FREIGHT TRUCK TRAFFIC ASSOCIATED WITH THE PORT OF OAKLAND: A CASE STUDY OF ROADWAY IMPACTS

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James Hinkamp

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COMMITTEE MEMBERSHIP

TITLE:	Freight Truck Traffic Associated with The Port of Oakland: A Case Study of Roadway Impacts
AUTHOR:	James Hinkamp
DATE SUBMITTED:	December 2011
COMMITTEE CHAIR:	Cornelius Nuworsoo, Ph.D. *Associate Professor* Department of City & Regional Planning
COMMITTEE MEMBER:	Chris Clark, J.D. *Lecturer* Department of City & Regional Planning
COMMITTEE MEMBER:	Anurag Pande, Ph.D. *Assistant Professor* Department of Civil & Environmental Engineering

ABSTRACT

Freight Truck Traffic Associated with The Port of Oakland:
A Case Study of Roadway Impacts

By James Hinkamp

The Port of Oakland ("Port") is the 5th largest container seaport by volume in the U.S. and the largest in Northern California. Maritime shipping activity at the Port exceeds 2 million import and export twenty-foot equivalent unit (TEU) containers annually. Containers may be full or empty, but nonetheless typically require hinterland shipment and intermodal transfer between maritime and land-based freight distribution systems. The freight trucking mode ("drayage") handles approximately 80% of all TEU throughput at the Port, thus constituting the majority of landside Port traffic. The Port is also situated adjacent to dense urban development thereby exacting certain external impacts. Drayage impacts on regional roadway infrastructure proximate to the Port are explored, to expand knowledge of freight network conditions and relevant policies addressing the topic in the San Francisco Bay Area.

Statistical regression analysis and elasticity results estimate a certain level of impact on nearby freight corridors of I-80, I-680, and I-880. Drayage traffic has continued to increase since 2000, as a function of increasing TEU throughput occurring at the Port. Policies to address stable freight flow and infrastructure maintenance are ongoing, although additional studies are also recommended to ascertain comprehensive network impacts.

Keywords: Port of Oakland, Twenty-foot equivalent units, drayage, pavement, impacts

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Justin Fox, Director of Rail Services, Wilbur Smith Associates
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Delphine Prevost, Senior Maritime Projects Administrator, Port of Oakland
Ricky Sun, Maritime Business & Development Representative, Port of Oakland
Rick Turri, CEO, Arrow Trucking
Carol Carevich Wianecki, Property Manager, Port of Los Angeles

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1. Introduction

"It is not money but the volume of goods and services which determines whether a country is poverty stricken or prosperous"

- Thomas Sowell

1.1. Overview

Worldwide freight transport has outpaced passenger transport in recent years (Gilbert & Perl, 2008, p. 101). This development poses several challenges. Not only will increasing traffic volumes across travel modes compete spatially and temporally, but entire regions must cope with potential congestion and resultant impacts, such as environmental degradation, rising energy consumption, and infrastructure damage. This study explores port-related freight truck transportation impacts on roadway infrastructure.

Maritime freight volumes are expected to double 2001 levels by the year 2020; as of 2010, more than 2 billion import and export tons of cargo traversed US waterways annually (American Association of Port Authorities, 2010). Expanding demand also engenders necessary infrastructure to assimilate maritime cargo via seaports. Freight trucking, also called "drayage", and freight rail are common land bearing transport modes capable of distributing massive cargo volumes to inland markets.

Seaports are uniquely positioned as cargo facilitators and contribute to freight transport overseas and overland. Thus, seaports are vital regional trade facilities that may also have significant international influence in terms of cargo handling capabilities; an accommodating seaport can promote increased trade volumes in tonnage and value, and benefit national economies. The ability of a seaport to host efficient freight forwarding operations is crucial since 99.4% of international cargo, by weight, occurs via seaport intermodal operations transport (AAPA, 2010). Landside logistics can be influenced by seaport trade and vice versa. In order to maximize goods movement between sea and land – intermodally – trucks and rail freight provide key mobility options to deliver cargo. Coupled with logistical innovations, such as just-in-time (JIT) production schedules, freight transportation has become a critical component of national economic salability.

1.11. Research Question(s)

Research questions motivate academic research and provide platforms for advancing knowledge within the field of study. The questions underlying this research effort span exploratory investigation to policy considerations:

- How has freight traffic associated with the Port of Oakland impacted regional corridor infrastructure?
- How may multimodal freight traffic systems become even more efficient in the Bay Area?
- Do existing policies support freight network innovation?
- What alternatives are available for future implementation?

1.12. Hypothesis

The Port of Oakland affects a portion of Bay Area drayage volumes, such that container throughput volumes are related to truck traffic impacts on regional freight corridors. Thus, it is presumed that a link exists between maritime and overland freight movement volumes.

It is also hypothesized that truck traffic impacts roadways more substantially than general automobile traffic. Freight-laden drayage entails exponentially greater gross weight values than do light-duty vehicles, such as personal, light-duty trucks and automobiles. As a result, it is expected that any increase in truck traffic volumes will adversely impact roadway serviceability at accelerated rates relative to pavement design periods.

1.2. Report Components

The thesis report is a case study, an exploratory effort to better understand the relationship between port operations and overland freight distribution. Resultant impacts of drayage related to port operations are studied specifically along certain regional freight corridors near the Port of Oakland, located in the San Francisco Bay Area ("Bay Area"). The report encompasses multiple chapters emphasizing distinct aspects of the study.

Chapter 2. Background

Case study context is established in this chapter, to develop foundational treatment of study objectives and motivation; background information in this report is largely qualitative. This section specifically investigates freight transportation sector characteristics, including logistics theory and history, in addition to current and historical operations at the Port of Oakland. Exploration of port operations further unveils freight shipping dynamics of drayage and container throughput.

Chapter 3. Methodology

This chapter examines applicable study methodologies capable of testing the relationship between port operations and drayage impacts on regional freight corridors. In order to test such impacts, study parameters are vetted. Academic literature and professional reports contribute advanced field knowledge to justify methodological decisions; where existing literature is not applicable or established methods require modification, adjustments to the research process are noted as well. This report utilizes established methods for selecting relevant commodity and port-specific truck data. Literature conclusively identifies commodity throughput levels as vital variables for any study of associated trucking impacts. Similarly, existing professional studies provide proven port-related truck data methods pursued in this study.

The methods applied to test the relationship between port activity and drayage impacts on roadways are quantitative in nature. Descriptive and inferential statistics are paired with elasticity analysis to determine regional freight truck volume responsiveness to container throughput at the Port of Oakland. The parametric relationship between drayage and container traffic imply certain pavement stress on study corridor surfaces.

Methods for identifying pavement stress levels are based on Caltrans' California Highway Design Manual (CA HDM) standards for pavement design, construction, and rehabilitation. The HDM Traffic Index (TI) mathematically estimates pavement impact levels on a 0-17.5 ascending scale. The TI formula is established as an appropriate measure to estimate study corridor pavement stress levels.

Chapter 4. Results & Analysis

Descriptive statistics articulate study period trends that occurred in the Study Area. Specific vehicular, freight, and infrastructural parameters are compared:

- Twenty-foot equivalent unit (TEU) throughput
- Average Annual Daily Truck Traffic (AADTT) v. Average Annual Daily Traffic (AADT)
- AADTT v. TEUs
- TEU-Qualified Truck volumes v. TEUs
- TI calculations

Inferential statistics report specific values computed via linear regression analysis. Parametric comparisons featured in descriptive statistical analysis are repeated. Relationships between drayage volumes and container throughput are correlated, to determine strength of variable relationship. Elasticity values of truck volumes with respect to TEU throughput are also reported.

Using the TI formula, study corridor pavement stress levels are estimated for the duration of the study period. Potential roadway impacts are also visualized, using prior local and regional agency surface condition surveys.

Chapter 5. Policy Considerations

Freight truck traffic effects on regional freight corridor pavement conditions are examined from a policy perspective. Study results are briefly reviewed as reference for possible systemic solutions. Literature review of freight truck traffic mitigation reveals a variety of available policy directions. Academic and professional reports are juxtaposed with existing statutes pertaining to freight traffic mitigation and related pavement rehabilitation solutions.

Current and proposed Port policies are also disseminated. Documents governing Port operations, such as the Charter of the City of Oakland and the Port Strategic Plan for 2011-2015, are available and reviewed for policy application. Some policies have produced specific programs, which are also analyzed in this study to assess the extent and effectiveness of implementation. Recommendations for future policy direction are devised, in terms of existing policy adjustment and new policy formation, where deemed feasible. Recommendations for further study are also included, to establish a platform for increasing contextual field knowledge.

Appendices

Data supporting report findings are stored in appendices numbered according to chapter relevance. For example, TI Index computation tables feature values informing pavement stress levels, and are stored in Appendix to Chapter 4 to supplement finished tables featured in Chapter 4: Results & Analysis. Appendices in this report hold raw data encountered during the research process in addition to data tables showing how relevant values were derived.

Chapter 2. Study Background

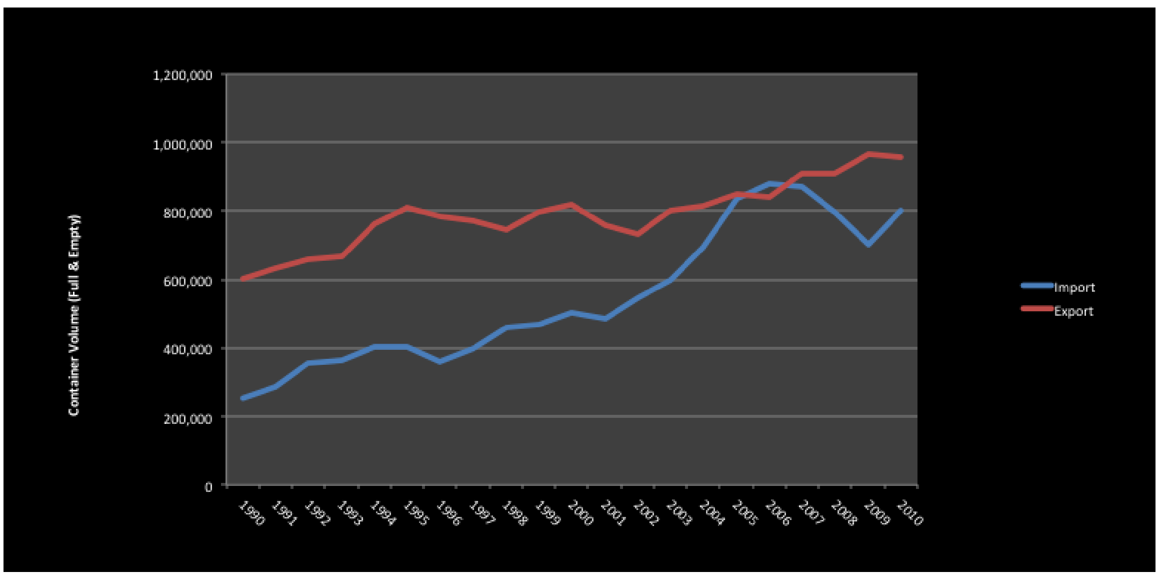
2.1. Study Purpose

Ports provide access to global markets by handling import and export cargo, require significant infrastructure massing, and host sophisticated logistical operations critical to cargo distribution. Port operations subsequently affect adjacent cities. Ports facilitate critical goods to consumer markets, contribute to city tax revenues, and "…[raise] the productivity of prime factors of production (labour and capital)." (Panayides, 2007, p. 27). Ports also impose certain costs. Air and water quality concerns associated with ports are actively studied and seek mitigation (Port of Oakland Comprehensive Truck Management Plan, 2009; Comtois & Slack, 2007). Freight traffic mixing with personal vehicle and transit traffic prompts safety concerns on roadways (Peeta et al., 2004, p. 117). Economic competitiveness of cities and regions may also be compromised by inefficient logistics, especially in overland freight transport (Carbone & Gouvernal, 2007; Notteboom & Rodrigue, 2007).

This study examines the importance of overland freight transportation mobility in city and regional planning efforts. Seaports manifest considerable transportation activity, especially with regards to goods movement. Generally, seaports are associated with imposing cranes and container yards, and predominantly occupy large swaths of land on city fringes; some ports are situated closer to maritime shipping lanes, while others are more proximate to production and consumption zones. Their significance, however, extends far beyond physical occupation of immense industrial land.

The San Francisco Bay Area region is growing, and so is multimodal freight activity at the Port of Oakland. From 1990 to 2009, container throughput increased 81.9%; imports represented 47.6% of the growth share while exports comprised 52.4% of the upward trend (see Figure 2.1). Expanding port operations to accommodate increased demand for goods engenders increased freight transportation volumes, which can subsequently affect infrastructural and economic capacities throughout the region. The scope of this research emphasizes landside freight logistics impacts adjacent to the Port. Impacts are defined in terms of traffic, infrastructure, and economic effects of landside Port shipping activities. Freight trucking and freight rail modes of transportation comprise the multimodal parameters of the study.

Figure 2-1. Historical Container Throughput at Port of Oakland 1990-2009



Source: Port of Oakland, 2011.

2.2. Freight Movement

In 2002, transportation related goods and services contributed over 10% ($1 trillion) to the U.S. Gross Domestic Product (GDP) (Bureau of Transportation Statistics, 2002). Ports are economic engines that significantly affect local, regional, and global markets daily. In just 13 years (1995-2008), international freight container traffic in the U.S. doubled (Bureau of Transportation Statistics, 2009), indicating a tremendous growth in access to international markets. Additionally, Bay Area economic sectors identified as being related to freight transportation employed 47% of the regional workforce in 2000 (Metropolitan Transportation Commission, 2004).

By virtue of their role in supply chain management of goods distribution, ports link material goods to diverse populations and organizations, such as government, military, private enterprises, and households. Ports handle mammoth amounts of material, both raw and refined, that are present in everyday life: household kitchen appliances, automobiles, and steel are finite examples among millions of aggregate and disaggregate items. The objective of this proposed thesis is to explore aforementioned port factors in a context-specific arena, through the examination of freight traffic and corresponding impacts on adjacent trade corridors.

2.2.1. Context: Port of Oakland & Adjacent Freight Corridors

Figure 2-2 shows The Port of Oakland (the "Port"), which is the largest container port in Northern-California and 5th largest by volume in the U.S. (AAPA, 2010). The Port estimates 99% of all cargo processed at the facility is containerized (Port of Oakland, 2010), of which a diverse range of commodities are imported and exported. Several similar commodities are handled as imports and exports, but vary considerably by value, depending on the direction of travel for a given commodity. Table 2.1 exhibits the 15 most common commodities handled by the Port, by value, for calendar year 2009.

Figure 2-2. Aerial View of Port of Oakland Container Seaport

The Port of Oakland is the primary container seaport in Northern California and 5th largest by volume in the U.S. International freight-laden vessels frequent the port to distribute and receive container cargo at assigned maritime terminal berths. (Photo source: ChamoisMoon.com)

Table 2-1. Port of Oakland Top 15 Commodities by Value, 2009

IMPORTS (Containerized)

Commodity	$ US	% Share
Beverages	1,098,462,862	5.5%
Electric Machinery	2,311,931,501	11.5%
Iron/Steel Products	383,759,415	1.9%
Machinery	4,505,059,595	22.4%
Medical Instruments	501,629,052	2.5%
Plastics	595,123,642	3.0%
Vehicles, Not Railway	791,443,226	3.9%
Furniture & Bedding	1,157,945,773	5.8%
Knit Apparel	965,170,995	4.8%
Woven Apparel	973,650,252	4.8%
Toys & Sports Equipment	670,669,726	3.3%
Spices, Coffee & Tea	425,327,598	2.1%
Ores, Slag, Ash	410,554,983	2.0%
Wood	362,203,666	1.8%
Misc. Textile Articles	337,771,124	1.7%
SUBTOTAL	**15,490,703,410**	**77.1%**
OTHER COMMODITIES	**4,602,879,290**	**22.9%**
TOTAL	**20,093,582,700**	**100.0%**

EXPORTS (Containerized)

Commodity	$ US	% Share
Beverages	546,447,853	5.3%
Electric Machinery	408,922,836	4.0%
Iron & Steel	185,612,282	1.8%
Machinery	652,968,766	6.3%
Medical Instruments	363,486,419	3.5%
Plastics	231,468,276	2.2%
Vehicles, Not Railway	472,425,475	4.6%
Edible Fruit & Nuts	1,802,488,645	17.5%
Meat	1,387,402,038	13.4%
Inorg Chem; Rare Earth Mt.	521,713,711	5.1%
Cereals	420,587,190	4.1%
Misc. Chemical Products	275,086,168	2.7%
Organic Chemicals	259,947,329	2.5%
Aluminum	202,256,021	2.0%
Hides & Skins	201,052,502	**1.9%**
SUBTOTAL	**7,931,865,511**	**76.9%**
OTHER COMMODITIES	**2,388,007,149**	**23.1%**
TOTAL	**10,319,872,660**	**100.0%**

Source: Port of Oakland, 2011.

Shipping operations fall under the purview of the Port's Maritime Division. The Port also contains 900 acres dedicated to sea, truck, and rail trade infrastructure (Port of Oakland, 2010). Thus, freight transport is an ubiquitous operation at the Port. There are 20 deepwater maritime berths, 35 container cranes (29 of which are Post-Panamax class). Panamax and Post-Panamax classifications refer to shipping vessel sizes relative to the capacity of the Panama Canal. Panamax vessels are technically within the passable requirements for traversing the Canal, while Post-Panamax vessels are considerably larger and cannot be accommodated at the present time. Current Panamax threshold for container vessels is dependent on physical vessel dimensions, including 294.1 meter length, 32.3 meter breadth (beam), and 12 meter draft (depth). Panamax dimensions equate to approximately 4,500-5,000 TEUs maximum load. Although, future upgrades to the Canal (2014) will feature wider, deeper passages capable of facilitating increasing vessels with capacities of up to 12,000 TEUs (GlobalSecurity.org, 2006).

As depicted in Figure 2-3, a major rail yard utilized by Burlington Northern-Santa Fe (BNSF) is located on Port property while Union Pacific Railroad (UPRR) operates a privately held rail yard adjacent to the southeast corner of the Port (Port of Oakland, 2010). Multimodal terminals owned by the Port are leased to freight operators that specialize in logistical operations, such as stevedoring, crane operation, container storage and tracking, and freight forwarding (Port of Oakland, 2010). The proximity of multiple freight modes is paramount to efficient intermodal cargo transfer between maritime and overland shipping.

Figure 2-3. Port of Oakland Intermodal Facilities

The Port of Oakland is strategically situated near multiple regional freight corridors and two freight rail yards for intermodal freight distribution. (Photo source: ChamoisMoon.com)

Freight transportation research dedicated to the Port and nearby freight highway corridors is limited. Existing case studies about the Port in the post-World War II era (the historical segway into modern container shipping) date from the early 1990s and prior (Campbell, 1993; Hayuth, 1982). Such research focused on the Port's ascension to international trade prominence and regional market share domination in maritime shipping activity in the Bay Area. Thus, landside effects stemming from Port trade - though noted – are not prevalent in academic forums. The Metropolitan Transportation-Commission (MTC), which serves as the Bay Area's Metropolitan Planning Organization (MPO), and other regional transportation authorities, have produced various truck travel demand models for the region. Most recently, Alameda County, which encompasses the Port and significant portions of adjacent freight corridors, contracted transportation consultants to develop an updated truck traffic demand model. The resultant report, titled *The Countywide Truck Travel Demand Model* estimates truck trip generation rates on local roadways, in addition to projecting future truck traffic volumes for 2015 and 2035. The MTC *Regional Goods Movement Study* (RGMS) also identifies three major freight corridors: the Central Corridor (Interstate 80), the Altamount Corridor (Interstate 580), and Interstate 880. However, due to data limitations, Interstate 680 was substituted for I-580 (see Section 3.6.4. Data Limitations, p. 62). I-680 was included due to the location of Weigh-in-Motion (WIM) stations along the corridor, which correspond to proximate freight traffic.

2.2.2. A Brief Port History

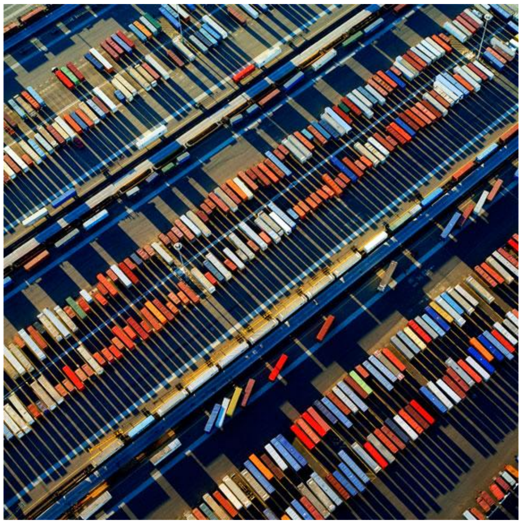
The Port maintains prestigious status as a gateway seaport with a rich history in maritime operations that continues today. However, the Port was not always the most active port in the Bay Area region. The Port began receiving maritime shipping vessels in 1927. The Port initially complemented larger cargo handling facilities across the San Francisco Bay, at the Port of San Francisco. Prior to the 1960s, the Port of San Francisco was the preeminent Bay Area seaport. The rise of containerization, however, promulgated the rise of the Port of Oakland as the superior Northern California seaport, in total cargo tonnage and value. Soon after implementing container-friendly infrastructure, attracting Matson, Sea Land, and other major maritime shippers to Oakland, the Port of Oakland became the world's 3rd-largest container port, trailing London and New York (Port of Oakland, 2000).

Several factors perpetuated this shift. First and foremost, Oakland possessed the land and infrastructure to accommodate the rapidly expanding overseas shipping industry. By contrast, San Francisco's "finger pier" infrastructure was outdated and outmoded; piers were aging and existing warehouses could not sufficiently store TEUs, let alone transport them with limited dockside space (Campbell, 1993, p. 228). Today, three major ports share freight handling duties in the Bay Area (with specialties): the Port of Oakland (container), Port of San Francisco (break-bulk), and Port of- Richmond (liquid bulk and auto). Asian economic resurgence continues to spur Pacific Rim trade which entails increased future demand for Port and Bay Area resources.

2.2.3. Multimodal Freight Logistics

Shortly after World War II a global shipping revolution occurred whereby traditional “break-bulk” cargo transport was consolidated into standardized containers, known as “twenty-foot equivalents”, or TEUs (Campbell, 1993; Slack, 2001). The implications of standardizing freight shipment included shifting supply chain management methods (Wang et al., 2007; Carbone & Gouvernal, 2007) and increased demand for hinterland access (Notteboom & Rodrigue, 2007). Figure 2-4 shows many different container sizes, which necessitate standardization to TEUs.

Figure 2-4. The TEU



Note the different physical sizes per stored TEU (above). TEUs are measured in 20-foot equivalent increments and have simplified cargo throughput as a standardized shipment unit of measurement. (Photo source: ChamoisMoon.com)

Logistics knowledge informs freight transportation as part of an economic system. Logistics is described as the "science of physical distribution" (Hesse & Rodrigue, 2004, p. 171), and is highly contingent upon freight transport. Freight transport, also referred to as "cargo movement" or "goods movement" is not merely the physical movement of goods from origin to destination, but also a logistical exercise in precise handling, distribution, storage, and delivery of commodities. Necessary infrastructure often includes ports (sea and inland), inland distribution centers, warehouses, and national roadways and railways. Logistics have become a highly specialized process and consists of several economic components conducive to successful international trade. Within the logistics sector there are multiple users, such as material producers, freight forwarders, shippers, and receivers, and also multiple levels of distribution, including production, shipping, warehousing, and consumption. Consequently, logistical success is determined by integrating the various levels of the freight supply process.

Freight transportation is thus an integral component of globalized trade and international supply chain logistics. The freight transport sector has increased its share of logistics costs, from 46.5% in 1980 to 58.6% in 2000, indicating a reduction in expensive inventories and greater proportion of goods in transit (Hesse & Rodrigue, 2004, p. 180). Just-in-time production models and the importance of economies of scale also necessitate logistical integration.

There are many logistical impacts associated with Port operations. The methods for deriving freight transport impacts are often different from traditional transportation analyses for several reasons. Logistical advances have ensured that temporal factors, such as just-in-time production and shrinking inventory (i.e., warehousing industries), make efficiency paramount. Aberrations in freight operations magnify impacts related to traffic efficiency. Approaches to modeling impacts are evaluated in the Methodology section, to ascertain the state of practice of impact analysis and to identify potential factors for incorporation into chosen methods.

2.3. Impacts

Impacts relate to possible consequences of port operations and may incur costs or benefits to affected freight systems. Traffic, infrastructure, and economic impacts are identified as critical factors for regional freight corridor planning and freight network systems near the Port of Oakland. Traffic impacts stemming from port operations typically result from continually increasing economies of scale in maritime shipments, which facilitates greater container throughput and has resulted in millions of annual ton-miles traveled in the Bay Area alone. Additionally, elevated freight traffic corresponds to infrastructure impacts, such that freight network efficiency is crucial to maintain expected reliability plus efficiency standards capable of shipping freight at competitive costs.

2.3.1. Traffic Impacts

Industry-wide integration in maritime shipping continues to significantly affect landside freight operations. Economies of scale are greatest at sea, aboard Post-Panamax vessels capable of carrying thousands of TEUs, but containers are ultimately bound for land where they are disbursed via freight truck and rail. The flow of import and export commodities subsequently affect traffic volumes required to handle variable TEU throughput rates. The most recent U.S. Commodity Flow Survey (2007) indicates 42,683,000 freight tons were imported by freight truck, rail, and air to the San Jose-San Francisco-Oakland Combined Statistical Area; air was included in this assessment since it entailed truck movements as well. Corresponding freight ton-miles in the Bay Area, or the distance traveled by freight, was 45,658 ton-miles (1.3% of national volume) (U.S. Commodity Flow Survey, 2007).

2.3.2. Infrastructure Impacts

Numerous reports and studies indicate concern regarding U.S. infrastructure freight-handling capabilities. Cottrill (2001) notes a "trend [that] is toward bigger ships that yield economies of scale both in the amount of cargo carried per ship and the landside operations needed to load and offload…The influx of cargo from large container ships requires efficient road and rail links to and from port areas" (p. 17). Increasing container volumes are associated with increasing demand for multimodal freight distribution. Given the expense of commodity inventory, the need for logistical efficiency follows that adequate capacity and acceptable freight corridor conditions are paramount to successful multimodal freight operability. Roso, Woxenius, and Lumsden (2009) explicitly conclude hinterland access is limited due growing trade demand, while also stating that landside freight transport has failed to replicate the rapidity of maritime shipping volumes (p. 338).

By virtue of sheer weight, freight trucks hauling TEUs impact roadways more severely than automobiles and other passenger vehicles. Such roadway impacts can be exacerbated in heavily trafficked corridors that provide regional access to inland distribution centers and consumer markets. Pavement may endure disproportionate stress along freight corridors, relative to other roadways.

2.3.3. Economic Impacts

Hesse & Rodrigue (2004) write that gateways and hubs (ports and airports), plus highway access to markets are increasingly important in freight distribution (p. 177). Logistical demands drive freight transport, based on the economic principle of incentives whereby efficient travel and multimodalism is rewarded with increased goods movement and profitability through mobility, as opposed to inventory costs and stagnant fleets. the Ports also entail a “value-added” element. Goods values – and the value of logistics services provided - can appreciate by virtue of sound port handling (as cited in Panayides, 2007, p. 30). This appreciation is then justified by business satisfaction in market participation and competitiveness (Panayides, 2007).

Research offers insight into recent changing dynamics regarding port operations and relationships to urban areas in general (Ducruet, 2007; Hayuth, 1982, 2007; Thompson & Taniguchi, 2001). As previously iterated, ports have assumed a more distinct role in logistics planning (Panayides, 2007). However, logistical integration does not necessarily guarantee regional economic benefits. De Langen (2007) remarks that, although ports were more strongly correlated with economic development during 20^{th} century, personal income levels have consistently lowered in port regions, along with a stated lack of connection between throughput levels and overall regional economic stimulus (p. 201). Hayuth (2007) concurs – ports and their city counterparts are often at odds over spatial constraints and economic "loosening" – thus, ports' direct economic ties have generally weakened with revolutionary logistics processes that no longer merit prior levels of on-site stevedoring and warehousing (p. 142-143). However, ports also generate "economic impact multiplier[s]", whereby port activity in a given region has direct and indirect effect on employment and business development (Hayuth, 2007, p. 143). Thompson & Taniguchi (2001) add that freight vehicle advances as a method of meeting real time demands (p. 397), have lowered transport costs.

In light of literature review of corresponding freight movement impacts, this study concentrates on traffic and infrastructure impacts. Relevant economic impacts are noted in terms roadway serviceability effects on the logistical operations of efficient goods movement. Adequate freight corridor pavement conditions are necessary to realize optimal container throughput levels and are increasingly important as container volumes rise at the Port of Oakland.

2.4. Conclusion

Increasing global freight demand is acknowledged and engenders significant challenges for future transportation and logistics networks. Cottrill (2001) reinforces the notion that, "…freight industry is market-driven and has a global, not a regional, perspective because it support international supply chains. In other words, freight shippers want a seamless transportation system to move their goods" (p. 18). The Port of Oakland, which primarily serves container freight movement, is particularly immersed in the global supply chain.

The impacts of evolving freight demand at the Port of Oakland are of question in this study. The next chapter will discuss methodologies available to model freight trucking impacts on regional roadways proximate to seaports, based on Port of Oakland container throughput levels. Academic and private sector literature is reviewed and applied where practicable. Systemic definitions and study parameters are further detailed in this effort, particularly with respect to infrastructure components, such as Census Count and Weigh in Motion (WIM) stations that detect truck travel on freight corridors throughout California.

Chapter 3. Research Methodology & State of the Art

3.1. Introduction

Heavy vehicles undoubtedly incur proportionally greater roadway damage by sheer mass than do personal vehicles (including light-duty trucks) (Bai et al., 2009, p. 19). The question remains, to what *extent* do heavy vehicles impact specific corridors, relative to commodity flows? The methodology used in this study incorporates statistical analyses based on sampling procedures validated by previous Bay Area truck volume studies. The Bay Area Air Quality Management District (BAAQMD) West Oakland Truck Study (2009) and Alameda County Congestion Management Agency (ACCMA) Countywide Truck Travel Demand Model (2010) are foundational reports for this study. Methodologies related to aforementioned reports supplement other studies on truck travel modeling and trucking pavement impact theories.

In efforts to capture truck traffic correlated to Port operations, it would be remiss to categorize all heavy vehicles homogeneously. According to FHWA vehicle classification standards, personal vehicles hauling recreational trailers, in addition to recreational vehicles themselves, also represent heavy vehicles. For study purposes, cluster sampling hones on drayage (freight) trucks most likely to haul Port commodities, in the form of twenty-foot equivalent units (TEUs). The BAAQMD West Oakland Truck Study (2009) developed a specific container truck classification model, founded on axle placement, which is emulated in this study, and described in further detail in this chapter.

The study methodology is exploratory in nature, to develop a greater understanding of combined seaport and freight truck operations as they pertain to the San Francisco Bay Area region. Secondary data informs the study due to its availability and topical breadth from which to advance knowledge regarding past, current, and future considerations on the subject of Port-related truck movements in the Bay Area.

3.1.1. Overview of Data Sources & Collection Methods

Studying the relationship between seaport container throughput and regional truck impacts is primarily a quantitative exercise. Statistical parameters entail variables representative of the study objective, which emphasizes containerized freight and truck volume data. Such parameters are based on data mined from existing professional reports of public and private agencies, in addition to transportation databases from the State of California Department of Transportation (Caltrans).

Freight and traffic data are measured in volume, vehicle classification, weight, and value; for purposes of studying infrastructural impacts, volume and vehicle classification variables were most relevant. Exploring possible statistical relationships from one variable to the other entailed measures of association at the interval-ratio level. Further measures of association were reinforced via cross-elasticity calculations for sensitivity analysis, to determine the responsiveness of truck traffic with respect to container flow. The numerical qualities of freight and truck data dictated the interval-ratio classification.

Caltrans maintains a Performance Measurement System (PeMS), which provides real-time highway conditions throughout California. PeMS also acts as a data repository and features archived vehicle count data. Data from Mainline Census Stations featuring

Weigh-in-Motion (WIM) facilities was secured from the PeMS portal, including truck volumes, truck weights, and vehicle classification data.

3.1.2. Overview of Contributing Reports

Three foundational reports inform this study extensively. The Metropolitan Transportation Commission Regional Goods Movement Study (2004) reviews regional infrastructure, policies, and programs pertinent to freight distribution in the Bay Area. The BAAQMD West Oakland Truck Survey (2009) was commissioned to examine the environmental effects – notably, air quality and resultant health effects – of Port truck traffic in West Oakland neighborhoods adjacent to the Port. The report concluded that the West Oakland neighborhood, in fact, experiences a higher proportion of adverse health effects stemming from Port trucking operations, due to increased emissions relative to other Bay Area locales. The ACCMA Countywide Truck Travel Demand study (2010) improved upon previous studies related to truck movement in the Bay Area. Rigorous physical counts were performed with particular emphasis on Port facilities' traffic generation capabilities.

3.2. Defining the Study Area

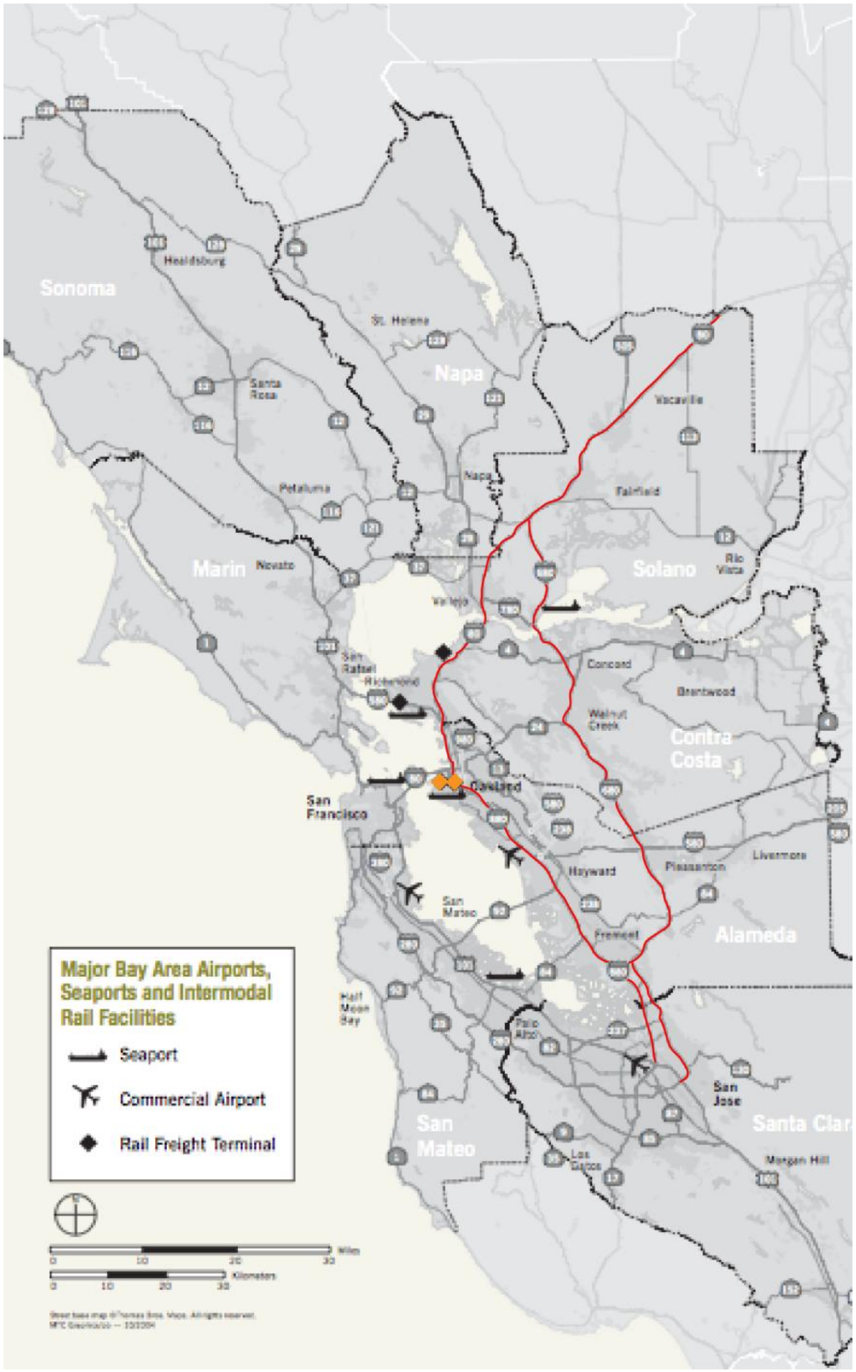
This study explores freight trucking impacts on roadways stemming from the Port of Oakland. This particular case study explores the Port's freight trucking impacts in a defined study area within the San Francisco Bay Area. The study area maintains a regional scope and contains geographic and infrastructural parameters.

Caltrans District 4 jurisdictional boundaries comprise the geographical extent of the study. Cordons of 20- and 50-mile radii were created to encircle the study area and capture existing Mainline Census Stations featuring WIM facilities within District 4; furthermore, Census Station/WIMs located along specific freight corridors proximate to the Port were targeted for measuring freight movement related to Port activity. The study area's geographic limits also correspond to regional lands under the auspices of the Association of Bay Area Governments (ABAG) and the Metropolitan Transportation Commission (MTC).

Major truck freight corridors represent the infrastructural parameters within the study area. In terms of total regional freight network, both freight trucking and rail corridors maintain distinct rights-of-way relative to each other, yet are generally parallel within the Bay Area, before diverging in Solano and Santa Clara counties, north and south of the Bay, respectively. The MTC defines specific freight-trucking corridors, two of which (I-80 and I-880) are included in this study as Figure 3-1. Interstate 680 was also included, by virtue of Mainline Census Station/WIM proximity to the Port and adjacent truck routes. Freight corridors included in this study are:

1. Central Corridor (Interstate 880-980 in Hayward @ Industrial Parkway)
2. Capitol Corridor (Interstate 80 in Pinole @ Appian Way)
3. Interstate 680 (Sunol @ Sheridan Road Interchange [TEU-Qualifed Trucks] & Jct. Rte 84 East [AADTT])

Figure 3-1. San Francisco Bay Area Freight Facilities Map



Source (base map): Metropolitan Transportation Commission. (2004). Regional Goods Movement Summary.

Source (freight corridor routing): James Hinkamp (2011).

3.3. Truck Sampling & Impacts

Truck sampling is influenced by the Port's specialization in container freight. The containers are typically hauled on trailer hitches (single-trailer – ST), thus precluding all single-unit (SU) trucks since the latter feature a conjoined chassis structure. Additionally, container trucks typically specify a 3-axle minimum setup (R. Turri, personal communication, November 30, 2011), although gross vehicle weight ultimately dictates maximum freight loads per California Vehicle Code §35550-35558 (Caltrans, 2009).

Typically, study truck classifications are a function of the weight of goods being transported. Specific regulations mandate weight-to-axle ratios such that freight tonnage must be supported by adequate numbers of vehicle axles. Caltrans denotes weight limitations and standards for safe freight distribution, based on the 2009 California Vehicle Code (§35550-35558). The BAAQMD's West Oakland Truck Survey (2009) further details distinctive freight truck types, especially those whose primary purpose is to transport twenty-foot equivalent units (TEU) of container freight. Yet, trucks designated for TEU carrying capacity are inclined to qualify based on axle values, rather than weight data. This is because TEU tonnage data remains limited. Thus, the definitions presented by the BAAQMD also inform vehicle class choices for the study samples included in this case study.

Container weights may vary greatly, depending on the types of commodities enclosed. Due to data limitations on container tonnage per trip, a range of truck classifications were considered for this study, in order to capture overland TEU volumes. Table 1 delineates the truck classification ranges for tracking commodity flow through census stations in the Study Area.

3.4. Data Collection

Disaggregated data detail is recommended to correlate seaport container traffic and truck traffic (Giuliano et al., 2007). However, only aggregated Port cargo data is provided by the Port. Truck traffic data was available in disaggregated form from Caltrans PeMS and the Caltrans Office of Truck Services. Due to the disparity in data detail between cargo and truck traffic study variables, use of correlative inferential statistics were required to develop discernable relationships (see Section 3.6.1. Statistical Analysis, p. 60).

3.4.1. Census Stations & WIMs

Caltrans' Performance Management System (PeMS) houses real-time traffic information and acts as an Archived Data User Service (ADUS). PeMS monitors all 12 Caltrans districts via roadway and other facility sensors, including cameras, embedded pavement sensors, such as induction loops, and bending plates. For the study years 2000 to 2009, PeMS contains relevant, disaggregated data on heavy-duty vehicle volumes, in addition to general traffic volumes, which can be discerned through search filters. These volumes differ from sampled Average Annual Daily Traffic (AADT) volumes and Average Annual Daily Truck Traffic (AADTT) volumes also compiled by Caltrans. AADT/T sampling methods are discussed in the *AADT/T Sampling* section.

Mainline Census Stations that included WIM facilities were targeted for this study based on truck-specific services. Few Mainline Census Stations incorporated the three primary traffic count variables of volume, vehicle classification, and truck weights. Those stations providing all three were thus chosen per proximate corridor. The count data retrieved from study Census Stations were acquired via bending plate sensors.

14 WIM sites are located within a 50-mile radius of the Port. However, PeMS sensor data for traffic volumes, truck weight, and vehicle classification are available for just 3 of the WIMS existing within 20 miles of the Port. Truck volumes, weights, and classifications have been collected at WIMS. Each variable corresponds to traffic and commodity volumes that may correlate to freight movement stemming from the Port.

The California Department of Transportation (Caltrans) identifies Weigh-in-Motion stations (WIMs) throughout the State. WIMs are operated by the California Highway Patrol (CHP), to monitor commercial vehicle axle loads, and associated carrying weights. The California Vehicle Code §2813 mandates that all commercial vehicle drivers stop at WIMS and related inspection stations (Caltrans, 2011) to mitigate adverse vehicle and road conditions, and to prevent traffic hazards. Thus, WIMS are enforcement facilities (Caltrans, 2011). The CHP operates Mainline and mini stations, however only Mainline stations apply within the study area since mini stations simply do not exist along identified study corridors. WIMS also collect pertinent truck data associated with freight distribution along goods movement corridors, in the form of truck weight. However, as container tonnage data remains limited for this study, truck volumes and classification variables served as primary input.

3.4.2. Vehicle Classification

Rationale for truck sampling is based on the BAAQMD's West Oakland Truck Survey (2009). Vehicle classification data was acquired via PeMS, following the BAAQMD's truck criteria. Tractor-trailer trucks are specifically suited to haul 20- to 40-

foot containers. The BAAQMD report indicates that containers are ***not*** typically transported via single-unit (SU) trucks since containers are mobile commodities in and of themselves, and must be able to hitch and unhitch from a truck trailer. The report explains, “Chassis trucks are tractors with an attached I-Beam chassis trailer. The I-Beam trailers as shown in Figure 3-2 are used to secure either 20 foot or 40 foot ribbed containers that are loaded or unloaded to/from cargo ships.” (BAAQMD, West Oakland Truck Survey, p. 17). Figure 3-2 (from the report) differentiates between I-beam and flatbed chasses. I-beams have narrower profiles, do not cover the tires, and provide support for loaded TEUs at corner castings toward the front and rear of the trailer. Contrarily, flatbeds are structured as planks over the length of the trailer.

Figure 3-2. Examples of Chassis and Flatbed Trucks

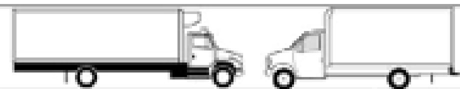
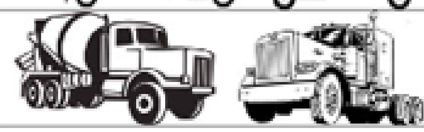
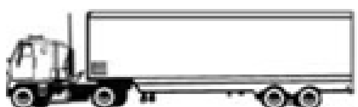
Source: BAAQMD, 2009, West Oakland Truck Survey, p. 18.

The West Oakland Truck Survey notes, “Container trailers for non-Port activities are typically 53 feet long with the container built on the chassis as a **single unit**…[**emphasis added**]…The Port trucks are easily differentiated from the non-drayage trucks based on their size and characteristic vertical ribbing and corner castings on the container.” (BAAQMD, West Oakland Truck Survey, p. 19).

Secondary data inference precludes utilizing visual criteria for Port truck sampling, but estimations could be based on appropriate axle values that were also supplied by the PeMS database. The West Oakland Truck Survey provides further overview of ranges in truck classification via *Table 5: Truck Classification by Number of*

Axles, which is reproduced here as Table 3-1. The aforementioned table exhibits general classifications from which Port-specific trucks were discerned in cluster sampling through PeMS database.

Table 3-1. Truck Classification by Number of Axles

Number of Axles	Example	Representative Truck
2 axles		Box Truck, Courier Van
3 axles		Bobtail truck, Cement Mixer, Package Delivery Van, Flat Bed, Moving Van
4 axles		Car-carrier, Tractor/trailer
5 axles		Port freight truck, gasoline tanker truck
6 or more axles		Tandem tractor/trailer

Chassis trucks are tractors with an attached I-Beam chassis trailer. The I-Beam trailers as shown in Figure 7 are used to secure either 20 foot or 40 foot ribbed containers that are loaded or unloaded to/from cargo ships.

Source: BAAQMD, 2009, West Oakland Truck Survey, p. 17.

From Table 3-1 (above), it can be derived that unloaded trucks (no trailer) may have just 2 axles, judging from the possibility of an empty 4-axle tractor/trailer truck. Trucks classified as having less than four axles, with single-trailer (ST) functionality, were thus included. Data estimation errors were mitigated by the ST classification, to avoid overly inclusive sampling of Box Trucks (2 axles), Cement Mixers (3 axles), and similar non-Port trucks.

Table 3-2 exhibits truck classification criteria used to retrieve archived data for Port-specific truck volumes along study corridors, from 2000 to 2009. The sampling variables reflect BAAQMD criteria to the extent possible, limiting error through single-unit (SU) truck exclusion. “User-defined” and “Unknown” vehicle classifications were also excluded due to definition ambiguity.

Table 3-2. PeMS Vehicle (Truck) Classification Data Search Inputs

Site Navigation (Drop-down menus & links)	Data Range
ep 1. D4: Bay Area (Caltrans District 4) ep 2. Facilities & Devices ep 3. Field Elements ep 4. Census Stations ep 5. Traffic Volumes ep 6. Mainline ep 7. Direction: Both ep 8. Vehicle Classification (By Class)	<u>Dates:</u> Jan 1-Sep 12; Sep 13-Dec 31 (2000-2009) <u>Locations:</u> I-80 Contra Costa Co. (Pinole, Appian Way) ID 49020 I-680 Alameda Co. (Sheridan Road Interchange) ID 49140 I-880 Alameda Co. (Hayward, Industrial Parkway) ID 49090
Included Vehicle Classification Terms (control variables)	**Excluded Vehicle Classification Terms**
< 4 Axle ST 5 Axle ST 6+ Axle ST < 5 Axle MT 6 Axle MT 7+ Axle MT	Motorcycles Cars 2 Axle, 4T SU Bus 2 Axle, 6T SU 3 Axle SU 4+ Axle SU User-Def Unknown

3.4.3. AADT/AADTT Sampling

Caltrans samples Annual Average Daily Traffic Volumes (AADT) and Annual Average Daily Truck Traffic Volumes (AADTT) at select mileposts along state highways each year, which is defined from October 1 to September 30 (Caltrans, 2010, p. iii). AADT volumes are functions of total annual volume collected divided by 365 count days (Caltrans, 2010, p. v). AADT counts are stratified into distinct time periods, including Annual (AADT), Peak Hour (Ahead & Back), and Peak Month (Ahead & Back).

AADT counts collected at highway mileposts are further delineated by “legs”, which indicate directionality relative to a particular milepost. Although some count locations rely on a specific directionality, such as “Ahead” counts, volumes are nonetheless recorded for both directions of travel (Caltrans, 2010, p. v.). Thus, counts for a single, labeled direction represent two-way travel at that location. Caltrans specifies seven leg classifications in its count data as defined in Table 3-3.

Ahead (A) and Equal (O) AADTT counts were selected for consistency in leg selection across sample count mileposts. This was necessary because AADTT counts recorded on I-80 (at Appian Way) were counted Equal (O) and Back (B) during years 2003-2006, 2008, and 2009, effectively creating two counts for those singular years whereas other locations maintained single counts per year, primarily in Ahead (A) mode, on I-880 and I-680 at SR 84 E.

Table 3-3. Caltrans AADT Volume Count Terms and Definitions

Prefix	Term	Definition
A	Ahead	Traffic counts located North or East of count location
B	Back	Traffic counts located South or West of count location
S	Cross street	Traffic counts located at cross street intersections
N	Onramp	Traffic counts located on onramps
F	Offramp	Traffic counts located on offramps
O	Ahead & Back	Represents equal traffic volumes for Back & Ahead legs
X	Interchange	Traffic counts taken in middle of interchange

Source: Caltrans, 2010, p. v.

3.5. Literature Review

3.5.1. Academic v. Private Sector

Reliance on secondary data for estimating truck traffic impacts has been vetted in multiple sectors. Academia, public agencies, and private consultants have developed unique methods to effectively capture truck traffic flow. However, differentiation with respect to policy implications and practical implementation of sector findings and contributions exist.

3.5.2. Traffic Impacts

Winebrake et al. (2008) present recent research into intermodal freight modeling, but the methods are not of the traditional traffic volume paradigm. Instead – in keeping with the research intent – *tradeoffs* are assessed, to ascertain cost-benefits of certain intermodal freight decisions and how those decisions affect specific societal factors, such as energy resources, the environment, and the economy. Two "network optimization models" are identified as helpful in analyzing freight transport logistics: trans-shipment and shortest-path (p. 1007). The former encompasses broader, macro-level commodity supply and demand flows. Trans-shipment models exhibit logistics efficiencies, by delineating "least cost" distribution (p. 1007). The latter model, shortest-path, is not convincingly explained, yet it is clear that in both models, the apparently well-backed Dijkstra algorithm can be incorporated, as a method of determining least cost. The models' abilities to exhume costs in freight logistics research is valuable (p. 1007). GIS-based systems, such as TransCAD, are also very helpful, as linear programming for shortest-path analyses. In fact, the US Bureau of Transportation Statistics (BTS) has used shortest path algorithms via GIS to validate freight travel distances (p. 1007).

In light of background methods, three modeling categories are introduced: Routing & Logistics, Freight Systems, and Policy Tradeoff. Each category and associated characteristics are identified as follows (p. 1007):

a) Routing & Logistics basically aims for most efficient origin-destination freight route. A "single optimizing (controlling/independent) variable, such as time or distance" is a model staple (p. 1007); MapQuest and Google Maps are examples, although freight operators use similar models.

b) Freight Systems is a form of (macro) trans-shipment model that is network-focused. System-wide congestion or air quality impacts can be determined (p. 1007).

c) Policy Tradeoff is the authors' preferred model and accounts for a multitude of social factors, such as public health, infrastructure, and environmental issues, while identifying tradeoffs associated with policy decisions regarding such topics (p. 1007). It is explicitly non-route oriented, and thus, wholly policy-oriented. This method is intriguing for research purposes, but may require hybridization for integration into the thesis.

Freight truck traffic modeling research has produced variation within the topic, based on geographic, economic, and political considerations. Studies of vessel-to-land cargo transfers, and subsequent roadway volumes, have discerned freight truck traffic as a function of maritime vessel traffic and port facility efficiency (Pope et al., 1995; Klodzinski et al., 2004; Sarvareddy et al., 2005). Maritime and landside shipping operations are tied within logistical supply chains by intermodal transfer of goods and commodities. To account for intermodal system traffic, commodity-based flow is preferred (Holguin-Veras & Thorson, 2003). This is because freight traffic volume, especially in the context of container transport, entails both vehicle and commodity volumes. Furthermore, commodity flow can also signify *empty* container trips, as when containers are loaned to other ports for storage. Giuliano et al. (2007) and Holguin-Veras & Patil (2007) concur that commodity-based trip volumes more accurately capture freight traffic modeling. Thus, import and export cargo – originating from and destined to maritime vessels – can be correlated to inbound and outbound truck freight trips. Imports will delineate truck trip productions from the Port and exports signal truck trip attractions, to the Port.

3.5.3. Alternative Modeling Methodologies

Recent traffic modeling technologies have challenged the traditional UTMS process. Neural networking is a primary alternative model and has several subsidiaries. This system has not yet been adopted for large-scale transportation planning models, however, and is not used in this research.

Artificial neural networks (ANNs) are sophisticated traffic modeling systems capable of simulating freight movement. ANN subsets include back-propagation neural network (BPNN) and fully recurrent neural network (FRNN). Sarvareddy et al. (2005) assert ANN superiority over "generalized methods", such as those in the ITE's *Trip Generation Manual* (p. 113). By using BPNN and FRNN models, Sarvareddy et al. (2005) argue that significant errors may be reduced, due to the ANN subsets' dynamic capabilities (p. 113).

3.5.4. Reports Contributing to Basis of Study

<u>Metropolitan Transportation Commission Goods Movement Study</u>

The MTC acts as the Metropolitan Planning Organization (MPO) for the San Francisco Bay Area. MPO status invokes regional transportation planning authority for nine counties included in the metropolitan area. In 2004, the MTC released a Regional Goods Movement Study (RGMS) for the San Francisco Bay Area. The summary report identifies current and future freight trends, infrastructure, and policies related to facilities and affected communities throughout the region.

Truck traffic congestion is identified extensively in the report, an issue that provides thematic impetus for this study. The RGMS articulates distinct linkages between maritime and hinterland freight distribution in a variety of ways:

- International trade (via seaports and airports) is the fastest-growing goods movement sector (MTC, 2004, p. 3).

- Containerized cargo is also currently the largest and fastest-growing maritime freight segment (MTC, 2004, p. 3).

- Trucking comprises the largest freight modal share by weight and value, carrying 80.2% of freight by weight and 81.7% of freight by dollar amount in the Bay Area (MTC, 2004, p. 6).

<u>BAAQMD West Oakland Truck Survey</u>

The BAAQMD initiated a West Oakland truck traffic survey in 2008, in response to a California Air Resources Board (CARB) Health Risk Assessment (HRA) completed during the same year. The CARB study investigated diesel exhaust impacts on the proximate neighborhood to the port with results indicating particulate matter exposure was three times higher in West Oakland compared to average Bay Area levels and that 71% of particulate matter exposure is related to truck traffic (BAAQMD, 2009, p. ES-1). The CARB notes that, "…there were significant uncertainties associated with (1) estimates of truck volumes and routes in West Oakland and (2) estimates of the percentage of truck traffic (and therefore emissions and risk) attributable to activity at the Port of Oakland." (BAAQMD, 2009, p. ES-1).

The objective of the West Oakland Truck Survey was to detail environmental truck traffic impacts in the West Oakland neighborhood and minimize impact data error in order to more conclusively assess truck traffic impacts proximate to the Port. It was posited that "overall trucking emissions were potentially overestimated and the fraction of trucking emissions attributed to the Port of Oakland was underestimated" (BAAQMD, ES-2). The West Oakland Truck Survey accomplished its objective, in part, through rigorous truck sampling. Port-related trucks were classified and described in detail. Primary characteristics of Port trucks include I-beam trailers with ribbed TEUs, featuring corner castings (latches) for intermodal transferability; trucks sporting "bobcat" tails (no trailer with exposed rear axles) were considered "empty" loads and could be counted. The truck sampling standards developed by the BAAQMD, in conjunction with Sonoma Technologies, Inc. (STI), and West Oakland EIP consultants inform the study sampling techniques in data collected from PeMS.

The Countywide Truck Travel Demand Model

The Alameda County Congestion Management Agency (ACCMA) contracted transportation consultants, Cambridge Systematics, Inc., to review and update the county truck travel demand model, which was originally developed by the Bay Area MPO, the MTC, in 199x (ACCMA, 2010, ES-1). The ACCMA later merged with the Alameda County Transportation Improvement Authority (ACTIA) to form the Alameda County Transportation Commission (Alameda CTC). The primary purpose of the report was to develop more accurate truck travel forecasting methodology for Alameda County. The significance of such an undertaking is noted by the fact that "Alameda County has five of the top 10 most congested corridors in the Bay Area, and each of these corridors is a major truck route" (ACCMA, 2010, ES-1). Furthermore, major portions of corridors selected for this study exist within Alameda County, engendering specific geographical relevance.

ACCMA was able to employ field counts for vehicle classification at 60 arterial and highway locations with mixed manual and electronic counting methods (p. 4-9). The Countywide Truck Travel Demand Model validates PeMS data mining and utilization of Caltrans Truck AADT reports for truck traffic forecasting (p. 5-1); the ACCMA, however, was able to use secondary data supplemental to physical counts performed at strategic corridor locations. The ACCMA focused on 2005-2009 truck traffic data for long-term future traffic forecasting (p. 5-2), whereas this study maintains a decade-long longitudinal scope. The report also identifies the Port of Oakland as a "special generator" of traffic, notably truck traffic. The report presumes previously trip-based truck trip generation rates may have underestimated truck trips by 90 percent (p. 4-6).

3.5.5. Infrastructure Impacts

Methods for estimating pavement impacts due to truck traffic include engineering metrics based on weight per axle and capital cost allocations resulting from pavement wear. Engineering metrics factoring pavement stress from truckload weights focus on units of Equivalent Single Axle Loads (ESALs). Industry mainstays, notably the American Association of State Highway and Transportation Officials (AASHTO) and Caltrans, employ 18-kip (18,000 lb.) standards for ESALs.

The Caltrans Highway Design Manual (HDM) identifies three types of pavements acceptable for roadway construction: rigid, flexible, and composite (p. 610-1). Different pavement types incorporate distinct materials, such as concrete, asphalt mixes, and even recycled rubber tire components. Selection criterion for construction is based on “good engineering judgment utilizing the best information available…with systematic consideration of…[various] project specific conditions” (p. 610-1).

The Caltrans HDM also conveys effects of traffic on pavement engineering. Emphasis is placed on truck traffic and accompanying loads experienced over the course of accumulated travel volumes on highways. The Caltrans HDM specifies, “Truck traffic is the primary factor affecting pavement design life and its serviceability. Passenger cars and pickups are considered to have negligible effect when determining traffic loads.” (Caltrans HDM, 2009, p. 610-4). Truck traffic volume knowledge is thus critical to determining study corridor pavement conditions and is tabulated according to estimated Equivalent Single Axle Loads (ESALs) and represented by the Traffic Index (TI).

The TI is based on 10-, 20-, 30-, and 40-year design life standards, further informed by standard 18-kip ESALs, and help determine pavement thickness adequate for construction (p. 610-4). The HDM notes an alternative method for estimating truck traffic loads called Axle Load Spectra, however, it is deemed under development for possible future implementation (p. 610-4). This study extrapolates TI values based on TEU-Qualified Truck volumes. TI standards provided by Caltrans are detailed in Table 3-4.

Figure 3-4. Equation for Measuring TI on California Highways

$$TI = 9.0 \times \left(\frac{(ESAL \times LDF)}{10^6}\right)^{0.119}$$

Where:

TI = Traffic Index

ESAL = Total number of cumulative 18-kip Equivalent Single Axle Loads

LDF = Lane Distribution Factor (see Table 613.3B)

Source: Caltrans, 2009, Highway Design Manual, p. 610-5.

The calculation of traffic indices (TI) involves the conversion of ESALs for specific truck types and design life (Table 3-5) and Lane Distribution Factors (LDFs) that take into account the propensity for heavy vehicles to utilize outside lanes more frequently as indicated in Table 3-6 (Caltrans, 2009, p. 610-5).

Table 3-5. ESAL Constant Values

Vehicle Type (By Axle Classification)	10-Year Constants	20-Year Constants	30-Year Constants	40-Year Constants
2-axle trucks or buses	690	1,380	2,070	2,760
3-axle trucks or buses	1,840	3,680	5,520	7,360
4-axle trucks	2,940	5,880	8,820	11,760
5 or more-axle trucks	6,890	13,780	20,670	27,560

Source: Caltrans, 2009, Highway Design Manual, p. 610-6.

Table 3-6. Truck Lane Distribution Factors

Number of Mixed Flow Lanes in One Direction	Factors to be Applied to Projected Annual Average Daily Truck Traffic (AADTT)			
	Mixed Flow Lanes (see Notes 1, 2, 3 & 4)			
	Lane 1	Lane 2	Lane 3	Lane 4
One	1.0	-	-	-
Two	1.0	1.0	-	-
Three	0.2	0.8	0.8	-
Four	0.2	0.2	0.8	0.8

NOTES:
1. Lane 1 is next to the centerline or median.
2. For more than four lanes in one direction, use a factor of 0.8 for the outer two lanes plus any auxiliary/collector lanes, use a factor of 0.2 for other mixed flow through lanes.
3. For HOV lanes, use a factor of 0.2; however, the TI should be no less than 10 for a 20-year, or 11 for a 40-year pavement design life.
4. For lanes devoted exclusively to buses and/or trucks, use a factor of 1.0 based on projected AADTT of mixed-flow lanes for auxiliary and truck lanes, and a separate AADTT based on expected bus traffic for exclusive bus lanes.

Source: Caltrans, 2009, Highway Design Manual, p. 610-6.

ESAL constants are “multipliers” of truck volumes, based on truck type (Caltrans, 2009, p. 610-5). The values represent estimated total ESAL impacts for given truck types over a particular period of time. One may notice 5+ axle trucks incur exponentially greater ESAL impacts than the prior axle class (4-axle trucks). As featured in the Caltrans HDM, Table 613.3C reproduced as Table 3-7, ESAL values correspond to specific, minimum TI Index values. Therefore, the amount of ESALs impacting a highway corresponds directly to a minimum design standard for pavement construction, based on index scaling.

Table 3-7. ESAL Conversion to TI

ESAL [1]	TI [2]	ESAL [1]	TI [2]
4,710		6,600,000	
	5.0		11.5
10,900		9,490,000	
	5.5		12.0
23,500		13,500,000	
	6.0		12.5
47,300		18,900,000	
	6.5		13.0
89,800		26,100,000	
	7.0		13.5
164,000		35,600,000	
	7.5		14.0
288,000		48,100,000	
	8.0		14.5
487,000		64,300,000	
	8.5		15.0
798,000		84,700,000	
	9.0		15.5
1,270,000		112,000,000	
	9.5		16.0
1,980,000		144,000,000	
	10.0		16.5
3,020,000		186,000,000	
	10.5		17.0
4,500,000		238,000,000	
	11.0		17.5 [3]
6,600,000		303,000,000	

Notes:

(1) For ESALs less than 5,000 or greater than 300,000,000, use the TI equation to calculate design TI, see Index 613.3(3).

(2) The determination of the TI closer than 0.5 is not justified. No interpolations should be made.

(3) For TI's greater than 17.5, use the TI equation, see Index 613.3(3).

Source: Caltrans, 2009, Highway Design Manual, p. 610-7.

In addition to established design standards, an effort to model the capital costs of highway rehabilitation, related to increments in heavy truck traffic on New Brunswick highways, is presented by Bisson, Brander, and Innes (1985). The study improved upon past US highway studies completed by AASHTO et al., which were considered flawed due to the specificity of assigning pavement deterioration to vehicle classes and for omitting environmental exposure and conditions as additional contribution to pavement wear and tear (10). Thus, variables independent of traffic can be significant and should be considered as well.

Methodology involved simulated commodity movements, measured against baseline traffic volumes; the commodities in question were not handled via freight at the time of the study, but were used as variables that, if eventually added to truck payloads, would represent incremental pavement loads in daily traffic (11). Discerning the incremental load effects could correlate to temporal pavement rehabilitation and, if incremental loads proved more damaging, associated incremental costs could be assigned; rigid and flexible pavement designs were noted.

Considering the question of "how much pavement damage", in both sheer volume and costs, Barros (1985) employs a "straightforward" method of analysis with the AASHTO's 18-kip (18,000 lb.) equivalent axle load (EAL) parameter. The 18-kip EAL parameter measures pavement impact as a function of [the number of] axles and pavement dimensions with the final EAL impact of a given vehicle being the sum of EALs of each axle group (p. 1). "To predict the wear and tear actually sustained by a pavement, it is necessary to estimate the frequency with which each type of loading will be applied" (p. 1). Essentially, the traffic volume, by weight and frequency, is required to examine practical effects on specific roadways.

However, empirical analysis related to highway engineering is intriguing. Barros notes "Pavements are designed and constructed with the knowledge that they will ultimately wear out" (p. 3). Empirically based models of pavement serviceability incorporate materials, design elements, and construction techniques, correlated with service (p. 3). So, due to the specificity of pavement load capacities, it can be determined that a rigid pavement may be serviceable for a set number of years (ie, 20-year life), with a specific level of EAL exposure (ie, 10 million EALs), which would equal approximately 500,000 EALs/year (p. 3). Trucks will consume a certain percentage of the capacity and are typically allocated 10-30% of EAL capacity (p. 3-4). Conclusions are that overweight trucks, in fact, affect pavement EAL capacity, at a rate of 7.5% - that is, 7.5% more than legally weighted trucks.

3.6. Adopted Study Methodology

Secondary data sources inform methods and analysis in this endeavor. Giuliano et al. (2007) successfully pursued urban freight flows, via estimation, aimed at universal applicability to any freight transport network. Secondary data sources can also provide broad information. Munuzuir et al. (2009) used limited data as well, while acknowledging the complexities of freight traffic route irregularity, to develop trip generation and distribution models with related data, such as goods produced in associated travel analysis zones.

Longitudinal analysis, such as time series analysis, may complement traffic forecasts. Al-Deek et al. (2000) applied time series analysis to examine truck traffic movements over time, using disaggregated monthly freight unit data (p. 3). The application toward cargo volume also reinforces the concept of commodity flow modeling to determine freight distribution volume more accurately.

3.6.1. Statistical Analysis

Statistical comparisons involved in this study attempt to capture the relationship between seaport cargo throughput and truck volumes on local freight corridors. Linear regression analysis inferred the extent of the relationship between TEUs and truck variables. Subsequent sensitivity analysis complemented correlational models. Inferential statistics employs statistical modeling techniques to test research hypotheses using samples that possess characteristics indicative of a larger population (Healey, 2005, p. 149). Statistical modeling is predicated on the variable types tested. Data analyzed in this study represent exclusively interval-ratio variables – that is, entirely numerical in nature. Variables were assigned independent (X) and dependent (Y) variable classifications. Specifically, TEU throughput represented the independent variable tested, while AADTT volume was classified dependent on the freight variable.

3.6.2. Linear Regression Analysis

Comparison between TEU throughput and AADTT volume variables represents a bivariate measure of association at the interval-ratio level. The preferred statistical model to test the relationship between freight and truck traffic is linear regression. The linear regression model tests three primary aspects of two variables:

- Existence of a statistical relationship
- Strength of the relationship
- Direction of the relationship

Source: Healey, 2005, p. 394.

Scattergrams visually inform regression analysis by plotting points of dependent variable Y with respect to independent variable X (Y as a function of X – f(x)). The first question of whether a relationship exists or not can thus be observed based on the slope of the regression line. An association can be visually verified when the regression line maintains an angle from the x-axis (Healey, 2005, p. 396). Otherwise, a horizontal slope indicates negligible association.

Linear regression analysis informed the correlation between container flow and AADTT volumes at the chosen study locations. The results do not indicate cause and effect, but articulate the potential likelihood that TEU flow affects truck volumes through such locations.

3.6.3. Elasticity Analysis

Elasticity calculations delineate the sensitivity of changing conditions between two variables. It is defined as the "percentage change in demand for a 1% change in a decision attribute" (Sinha & Labi, 2007, p. 50). In economic terms, elasticity refers to price sensitivity with respect to changes in a given quantity (output). For transportation study purposes, elasticity applies as a travel demand modeling technique.

Elasticity was introduced for each study corridor truck volumes (AADTT and vehicle class), in addition to container throughput parameters. AADTT and vehicle classification were tested for sensitivity with respect to changes in TEU volumes over the study period (2000-2009). Specifically, elasticity was utilized and the effects of changing TEU volumes on truck volumes in study corridors was calculated to develop predictive values for future growth. Elasticity is appropriately applied to reveal sensitivities between complementary goods, such as container trucks and containers (see Sinha & Labi, 2007, 51-52).

3.6.4. Data Limitations

Acquired literature presents compelling methods for answering freight traffic impact queries, but data limitations persist – namely, fiscal and temporal constraints prevent extensive, rigorous manual traffic counts or digital modeling. Some primary data sources, especially in disaggregated form, were difficult to acquire. The final study parameters thus reflect data and ensuing analysis within the scope of accessible sources.

The MTC Regional Goods Movement Study identifies I-880 as the most traveled highway by trucks in the Bay Area, while I-580 is considered the primary connection between the Bay Area and the national interstate truck network (Cambridge Systematics, 2010, 1-1). However, PeMS data does not provide vehicle classification or truck weight filters for any Mainline census or WIM stations along the I-580 corridor. This omission precluded the corridor and requires further study to determine impacts explored in this exercise.

AADTT count locations on I-680 could not be retrieved on a one-to-one basis with general AADT counts along the same corridor. General AADT counts were taken at Sheridan Road Interchange (in the same location as the chosen I-680 Mainline WIM measurements) whereas AADTT counts were collected approximately 2.3 miles west at the route junction of State Highway 238 North and 2.5 miles east, at the route junction of State Route 84 East and West. Further examination revealed that counts taken at the route junction of I-680 and SR 84 East are the most geographically proximate to I-580, potentially capturing diverted truck traffic from the crucial I-580 corridor. Further discrepancies existed in AADTT counts during one year (2007) when only Back counts were available on I-80 at Appian Way.

PeMS databases, although detailed, featured missing data points for each variable (volume, class, weight) within each study year strata, in addition to unevenly matched archived years. The ACCMA also noted missing data point limitations in its countywide report (p. 5-7).

Truck

Attempts to retrieve primary drayage data from Port terminal operators, drayage operators, and the Port itself garnered minimal success either via non-response or simply from lack of available, disaggregate detail. In fact, the Port consistently refers to its website for public access to data, which is limited to aggregated annual goods volumes (imports/exports) and commodity types, in addition to international trade volumes based on origin/destination frequency.

Rail

Data concerning rail freight movement proved prohibitively difficult to acquire, precluding a full multimodal report. Port authorities and knowledgeable consultants acknowledge similar perceptions, especially regarding rail movements occurring off-site (D. Prevost, personal communication, November 22, 2010). Multiple attempts to contact freight rail representatives also proved futile. Conclusions derived from freight rail are thus limited to previously published reports and studies.

3.7. Conclusion

This study relies exclusively on secondary data pertinent to TEU movements stemming from the Port of Oakland. Use of secondary data to estimate freight flows has been vetted, especially by Giuliano et al. (2007). Study constraints related to data selection also exist, including temporal and data access limitations. Regarding available data, Caltrans archives provide information for certain freight corridors volume parameters, including AADTT and TEU-Qualified trucks. Drayage parameters were established with the aid of pre-existing professional reports indicating specific truck types most likely to haul Port of Oakland containers. Proximate study freight corridors were also selected to capture probable truck traffic related to Port of Oakland operations. The ensuing chapter reports results of freight truck estimation techniques applied to study corridors. Analysis infers the extent of impacts stemming from freight truck volume findings.

Chapter 4. Results & Analysis

4.1. Introduction

During the opening decade of the 21st century, Port commodity volumes maintained an upward trend, culminating with approximately 2 million combined imports and exports of twenty-foot equivalent units (TEUs) of container cargo in 2009. Annual containerized trade surpluses by volume persisted throughout the decade. Exports underlined overall growth in trade, except during 2006, when imports briefly overtook exports. Figure 4-1 visualizes Total Combined TEU volume trajectory for the study period. The decade-long trend reinforces the Port's export-driven status (see Figure 4-2). Downward deviations indicative of the recent economic recession are also evident, although container throughput levels in 2009 remained elevated over year 2000, representing an increase of 268,289 TEUs over the course of 10 years. Thus, approximately 26,800 additional TEUs flowed in and out of the Port each year during the 10-year study period, from 2000-2009.

Figure 4-1. Port of Oakland Total Combined TEU Throughput, 2000-2009

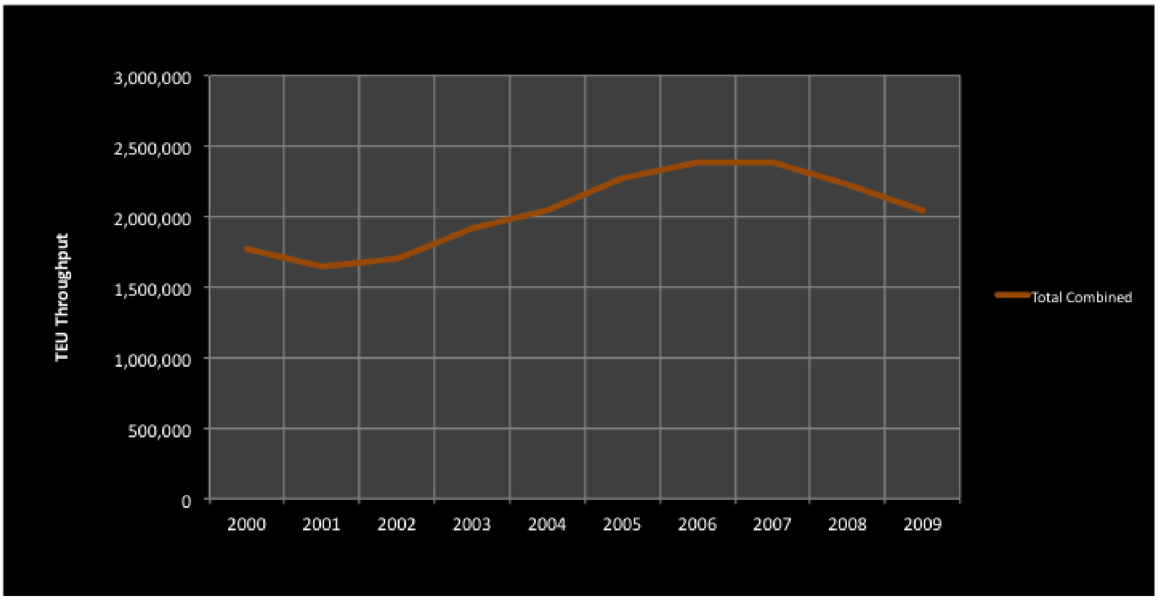
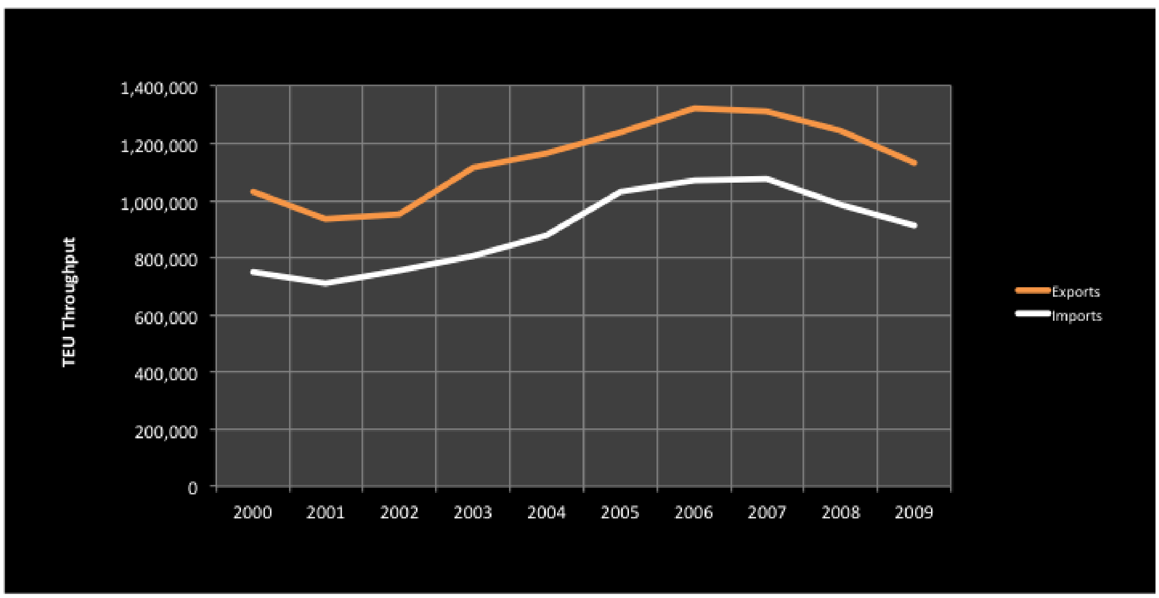


Figure 4-2. Port of Oakland Export v. Import TEU Throughput, 2000-2009



4.1.1. Methods Review

Initially, Average Annual Daily Truck Traffic (AADTT) volumes were compared with general Average Annual Daily Traffic (AADT) volumes, using linear regression analysis, to examine correlations between distinct roadway users along study corridors. Elasticity analysis between AADTTs and AADTs followed regression analysis.

The association between truck traffic and TEU volumes was subsequently tested with linear regression analysis as well. Elasticity analyses were also performed to discern the elasticity of truck volumes with respect to container flow. TEU volumes were stratified into three categories: Total Combined, Full, and Empty. Each freight stratum therein was compared to truck volumes on study corridors. Truck volumes were also parameterized by Average Annual Daily Truck Traffic (AADTT) and TEU-Qualified Truck classification; the latter refers to trucks classified by axle values comparable to Port-accessible truck characteristics.

Truck volumes specific to each study corridor exhibit unique correlations and elasticity with respect to and corresponding AADT and TEU volumes. The results are differentiated according to level of detail in truck volume data. AADTT volumes and TEU-Qualified Truck volumes are distinct. Each truck volume parameter was tested separately for statistical relationship and elasticity with respect to TEU volumes. All truck data was acquired from Caltrans repositories, although specific sources also varied between the two parameters. AADTT volumes represent aggregated truck traffic samples acquired from Caltrans Office of Truck Services whereas TEU-Qualified Truck volumes represent Port-specific truck classification from Caltrans Performance Management System (PeMS) archives.

PeMS vehicle classification data was limited relative to AADTT data. As a result, acquired values representing TEU-Qualified Truck versus TEU data are cautiously recognized. Coefficients of determination and sensitivity values are more informative at specific data points (years) within the study period in this case, as opposed to overall trends. Given the limited data set, statistical correlations between truck traffic and TEU volumes on I-80 and I-880 are generally stronger when comparing container flow to TEU-Qualified Trucks, which are defined according to BAAQMD-established truck count classifications (see Section 3.4.2. Vehicle Classification, p. 39); I-680 correlations and elasticity values are essentially nullified by the existence of only one data point (2006) for the TEU-Qualified Truck parameter.

4.2. Descriptive Results

4.2.1. Container Throughput

A trade surplus by volume for total TEUs persisted at the Port for all but one year (2006), when import levels trumped export levels (877,778 imports over 840,145 exports). Full and Empty TEUs, however, exhibit varying trends, which are notable for the correlative effects on regional truck traffic (see Section 4.3. Inferred Results, p. 80). Full container imports revealed strong growth from 2001 to 2005, with an exponential growth curve, before leveling between 2006 and 2007 and then beginning a downward trend thereafter. At peak levels in 2006, imports exceeded exports, indicating a trade deficit by volume; in fact, 2006 TEU volumes achieved a Port-record level of 2.4 million (Port of Oakland, 2007). After 2006, a distinct, negative Full import trend began and persisted through 2009, while Full exports continued to experience growth through the end of the decade (Figure 4-3).

Consistently strong export volumes imply continual overseas demand for goods, especially for raw, unfinished commodities, such as food crops, textiles, and (refer to Table 2.1. Port of Oakland Top 15 Commodities by Value, 2009, p. 21.). Contrary to Empty imports, Empty exports witnessed dramatic growth through 2006 before plummeting for the last three years of the study period; Empty import levels also digressed between 2000 and 2009, although net losses are gradual (Figure 4-4). Declines in both Empty export and import TEUs toward the latter part of the study period indicate higher utility for loaded containers. As containers were more likely to be loaded, truck impacts are also presumed to have increased correspondingly.

Figure 4-3. Port of Oakland Full TEU Throughput, 2000-2009

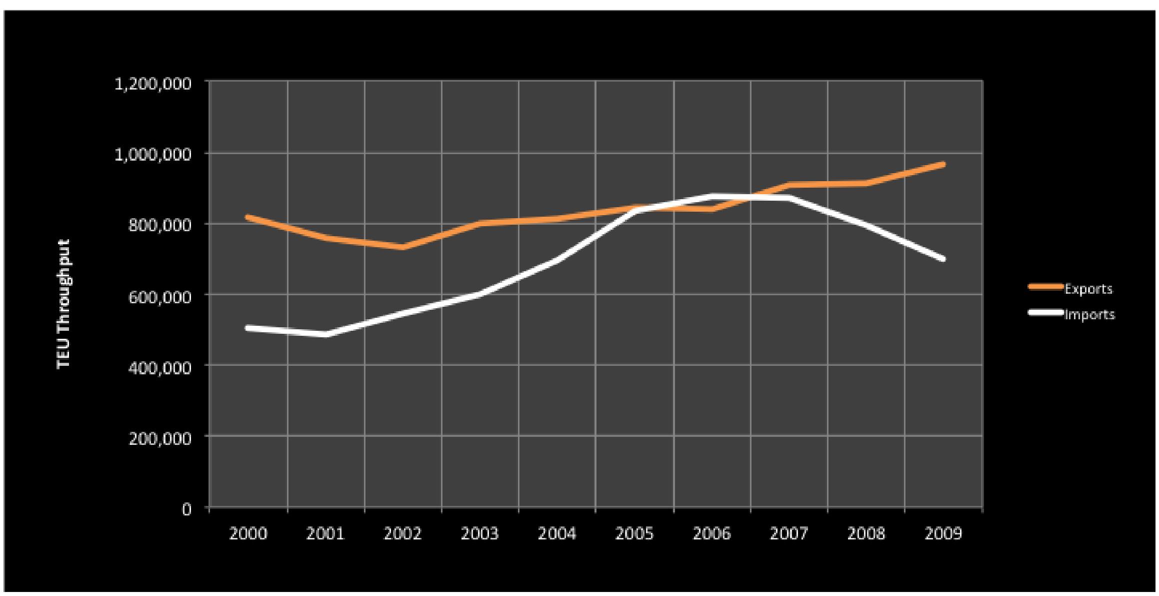
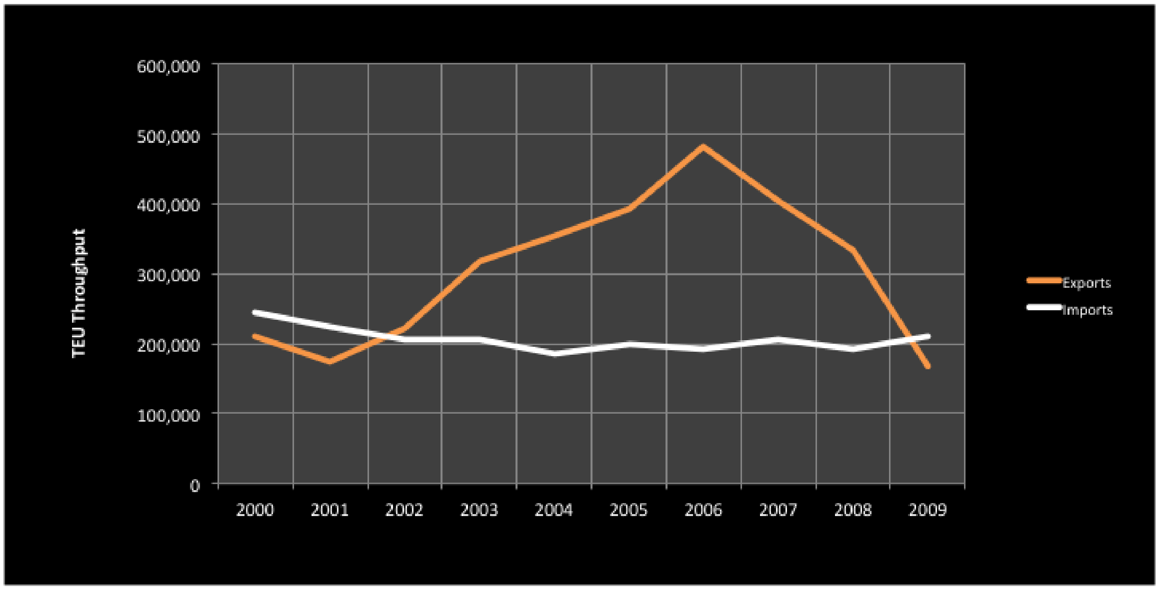


Figure 4-4. Port of Oakland Empty TEU Throughput, 2000-2009



4.2.2. AADTT v. AADT Volumes

From 2000 to 2009, I-80 and I-880 AADT volumes maintained relatively stable trends, with inflections most noticeable beginning in 2002 on I-880 and in 2003 on I-80. I-680 exhibited noticeably lower AADT volumes throughout the decade, but also recorded the most significant jump in volume (14.2%), from 2002 and 2003 (Figure 4-5). From 2003 to 2009, I-680 volumes continued to remain elevated above pre-2002 levels, although the corridor never realized volumes that match I-80 nor I-880. In fact, the I-680 volumes peak above approximately 150,000 AADT in 2006 whereas the latter corridors, I-80 and I-880, peak above 175,000 AADT and 225,000 AADT, respectively, during the same time.

Average AADTT share of AADT volumes ranged from 4.4% to 9.2% at study census stations (Table 4-1). I-80 traffic featured the least trucking proportional to general traffic volumes (4.4%), while I-680 handled the most relative truck traffic (9.2%);

trucking consistently contributed 5.9% of I-880 total AADT volumes. Elevated AADTT volume share on I-680 supports later revelations of strong truck versus TEU volume correlations along that corridor (see Section 4.3. Inferred Results, p. 83). Consistent volume share throughout the study period is interpreted to be a function of rounding AADT volumes to the nearest thousands value.

Figure 4-5. AADT Trends, 2000-2009

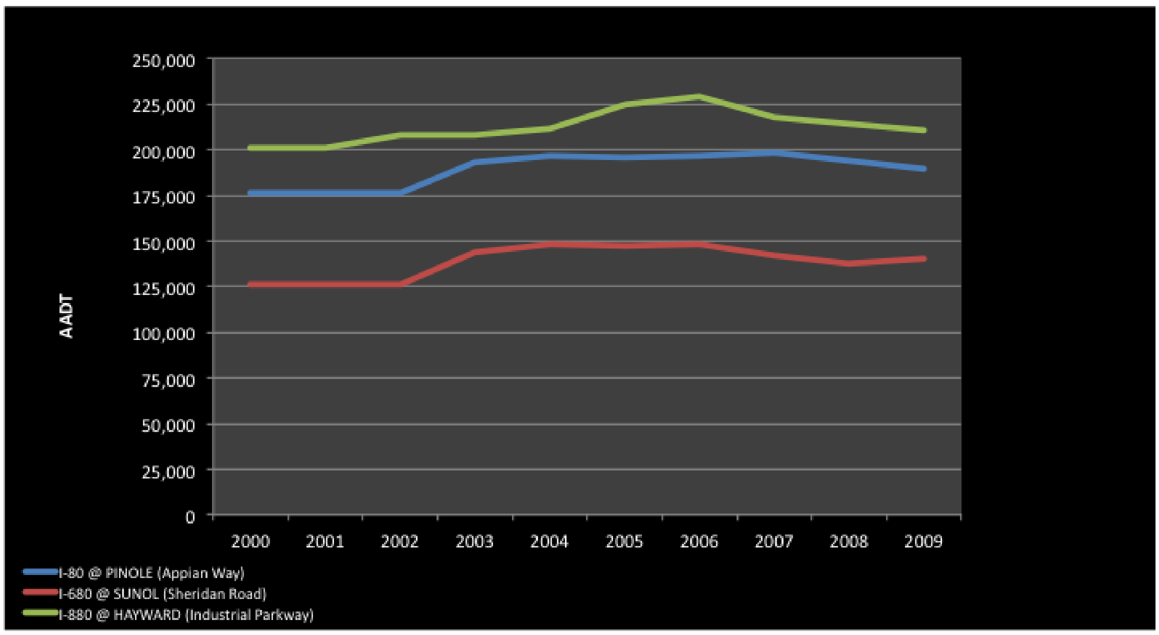


Table 4-1. Average AADTT Modal Share of AADT, 2000-2009

Location	AADTT Modal Share
I-80 @ PINOLE (Appian Way)	5.9%
I-680 @ SUNOL (Jct. Rte. 84 E.)	9.2%
I-880 @ HAYWARD (Industrial Parkway)	4.4%

4.2.3. AADTT v. TEU Volumes

Visual trends comparing AADTT to TEU volumes, for the duration of the study period, differed parametrically. AADTT trajectories are more gradual along respective study corridors (Figure 4-6) than the steeper Total Combined TEU volume trajectory (Figure 4-7). Differences in container and truck volume growth may reflect roadway capacity limits per corridor, such that the regional drayage capabilities could not match TEU throughput levels. Full export levels continued to rise through 2009, for example, whereas I-80 and I-880 AADTTs declined, and despite AADTT volume growth on I-680 during that year, TEU growth continued to outpace truck traffic. Yet, when Total Combined TEU throughput declined during the latter stages of the decade, AADTTs reflected this change as well, which inform correlations, and suggest import volumes may be more reflective of truck travel trends. More specifically, AADTTs appear to mimic Full import TEUs (Figure 4-8). The AADTT trend during the 2000-2009 decade indicates several possible conclusions:

- I-80 AADTT is lowest of the three study corridors throughout the study period. This may lead us to conclude that the proportion of roadway users operating heavy vehicles may also be the lowest among all study corridors. Similarly, I-680 may have a proportionately higher share of heavy vehicle users.

- I-880 AADTT remained higher than each of the other two corridors, most likely due to proximity to the Port, including direct on/off-ramps leading to and from Port access roads.

- I-880 and I-680 exhibited upward trends in AADTT volumes from 2004 to 2006, mirroring AADT spikes in 2005 and 2006, in addition to TEU import growth from 2001 to 2007 (Figure 4-9).

Overall, AADTT volumes more closely mimic Full *import* volumes as opposed to export volumes.

Figure 4-6. AADTT Trends, 2000-2009

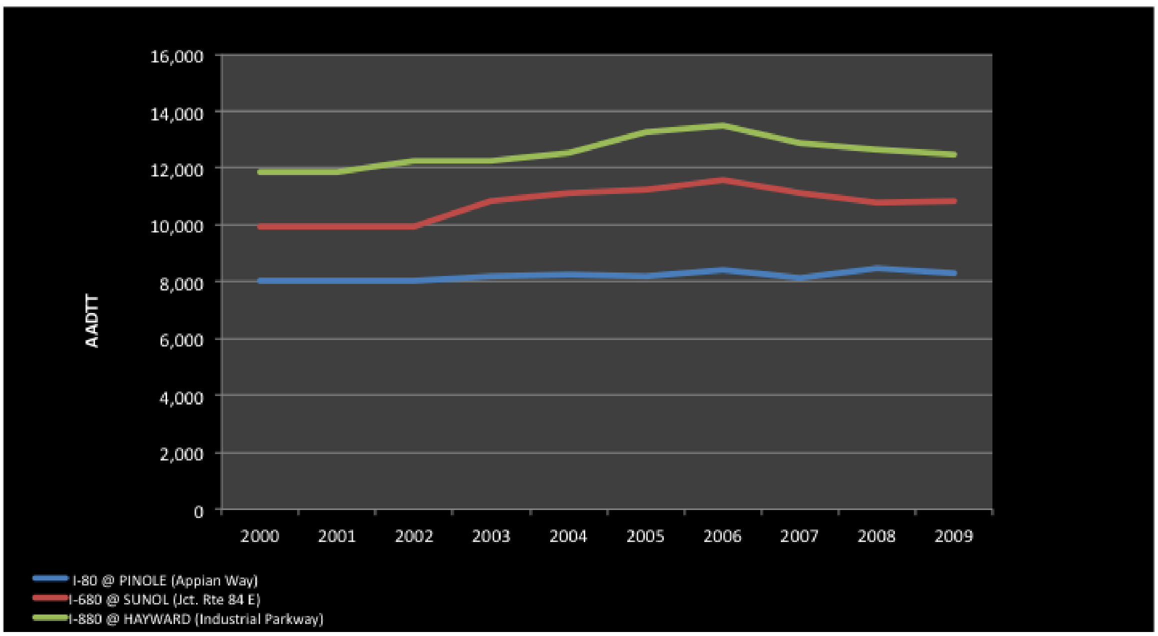


Figure 4-7. Port of Oakland Total Combined TEU Throughput, 2000-2009

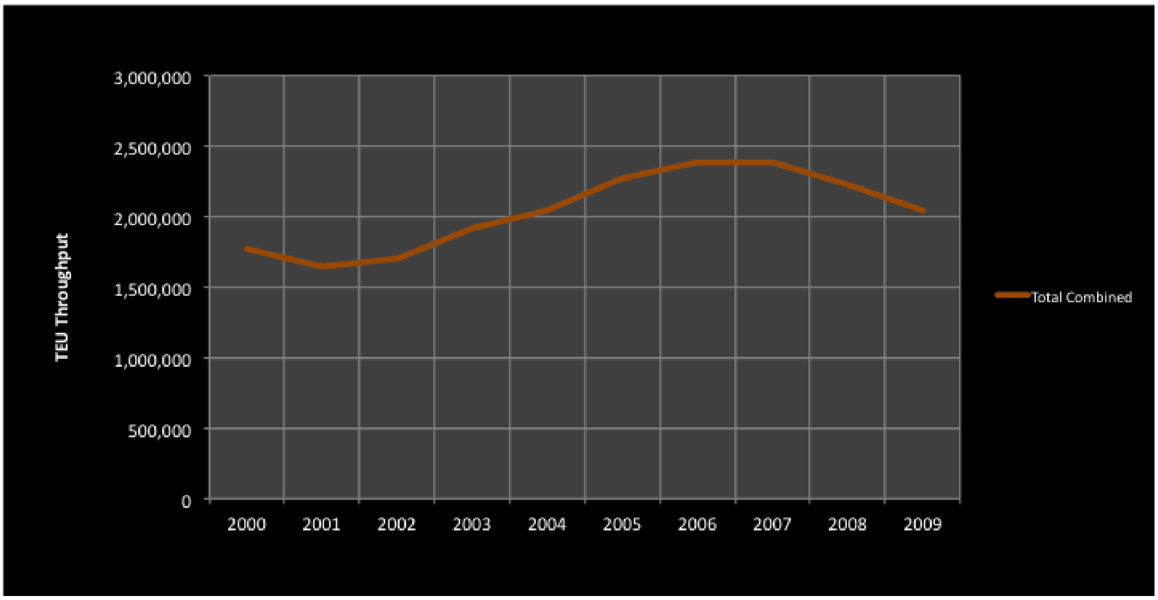


Figure 4-8. Full TEU Import Trend, 2000-2009

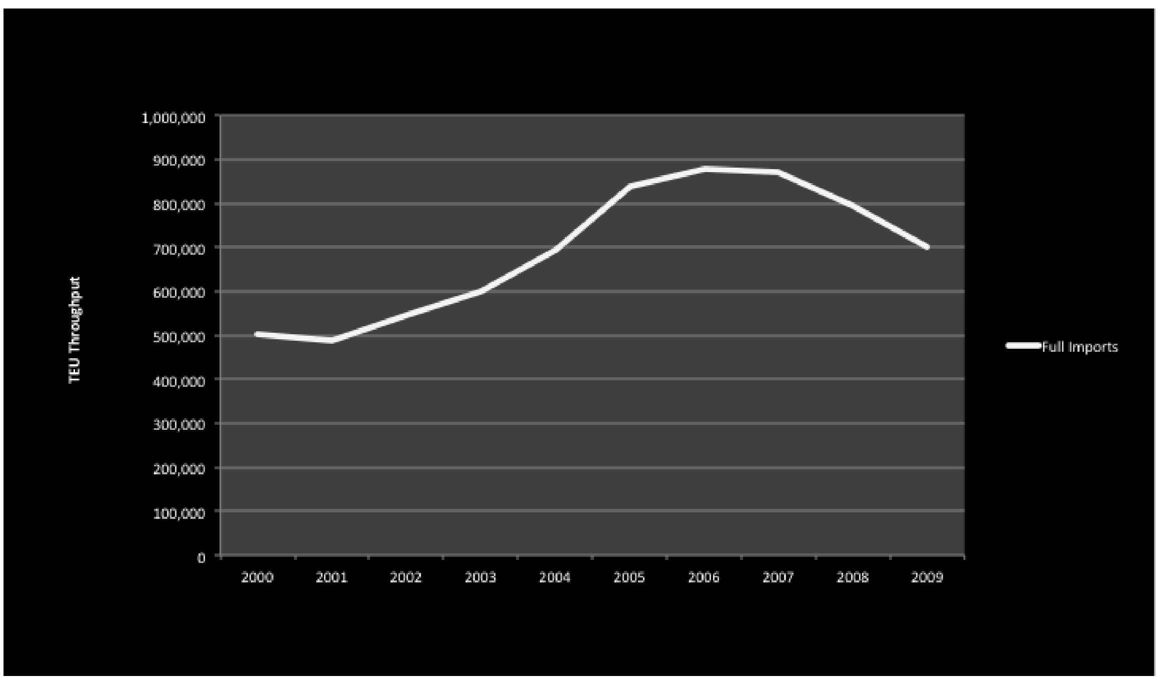
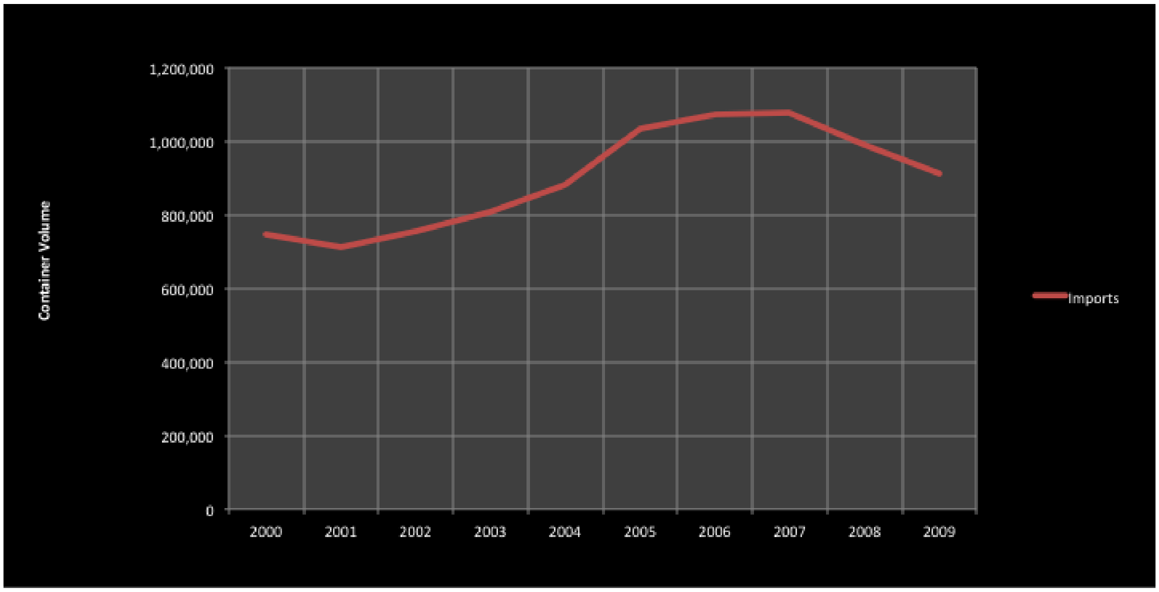


Figure 4-9. Import TEU Trend, 2000-2009



4.2.4. TEU-Qualified Truck v. TEU Volumes

TEU-Qualified Truck volumes provide more advanced insight on freight distribution stemming from the Port of Oakland; data was disaggregated by axle and trailer characteristics that match Port-specific trucks. TEU-Qualified Trucks are more likely, by virtue of Port-specific characteristics, to ship maritime containers.

TEU-Qualified truck volume data exhibit similar trends compared to AADTT volume trends, where corresponding data points are available. However, lack of TEU-Qualified truck volume data for I-680 effectively prevents meaningful comparisons for that study location, when comparing data to either TEU or AADTT volumes. Alameda County Congestion Management Agency (ACCMA) findings, regarding truck volumes acquired via PeMS, conclude that volumes declined “substantially” between 2005 and 2009 (2010, p. 5-10). Only TEU-Qualified Trucks on I-880 exhibited similar declining volumes toward the end of the study period, although the difference is not substantial – of seven observable years, TEU-Qualified Truck volumes in 2009 are the second-highest total for the study period.

For the study period, TEU-Qualified truck volume peaks differed between corridors. I-880 TEU-Qualified truck volumes peaked in 2007 whereas I-80 TEU-Qualified truck volumes peaked in 2009, potentially growing beyond the study period; I-680 trends are negligible (Figure 4-10).

TEU-Qualified Truck volumes track similarly to Total Combined TEU growth through 2006 (Figure 4-11). I-880 TEU-Qualified Trucks appear to trend more closely than I-80 trucks in this respect. Accordingly, it is presumed that Total Combined TEU throughput levels affected I-880 TEU-Qualified Trucks to the greatest extent among study corridors. Empty export TEUs also appear to mirror I-80 and I-880 truck volumes through 2006, although TEU-Qualified truck volumes continued to grow for at least another year on I-880 and three more years on I-80 (Figure 4-12), while Empty exports declined precipitously thereafter. This reflects previous findings implying greater utility for Full containers such that, despite fluctuating TEU-Qualified Truck volumes, trucks were more likely to carry Full TEUs through the end of the decade.

Figure 4-10. TEU-Qualified Truck Volume Trends, 2000-2009

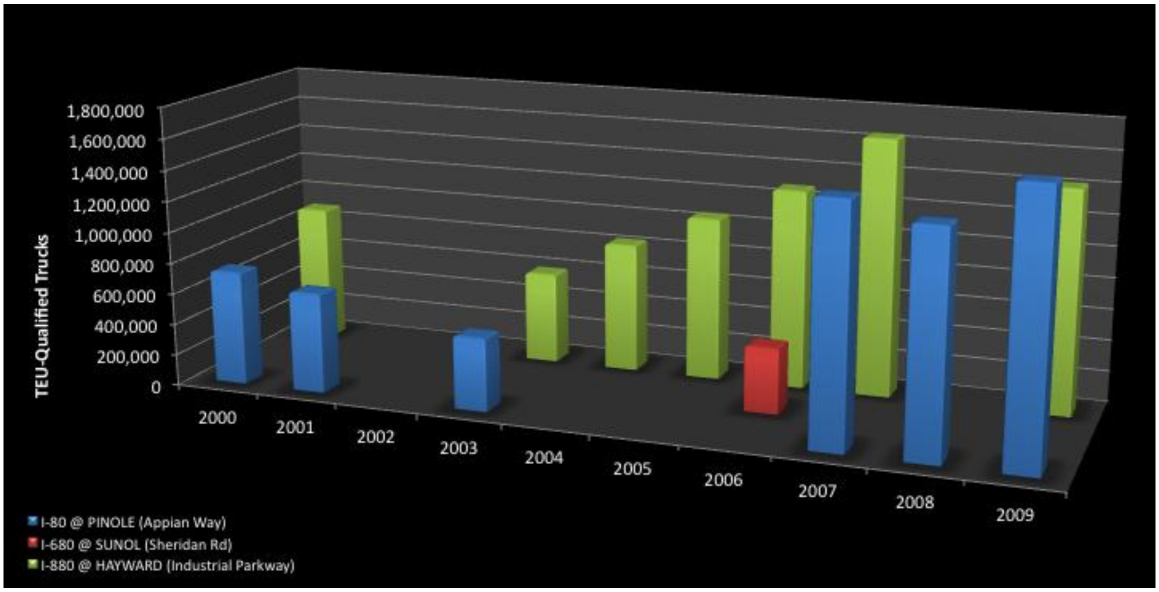


Figure 4-11. TEU-Qualified Trucks v. Total Combined TEUs, 2000-2009

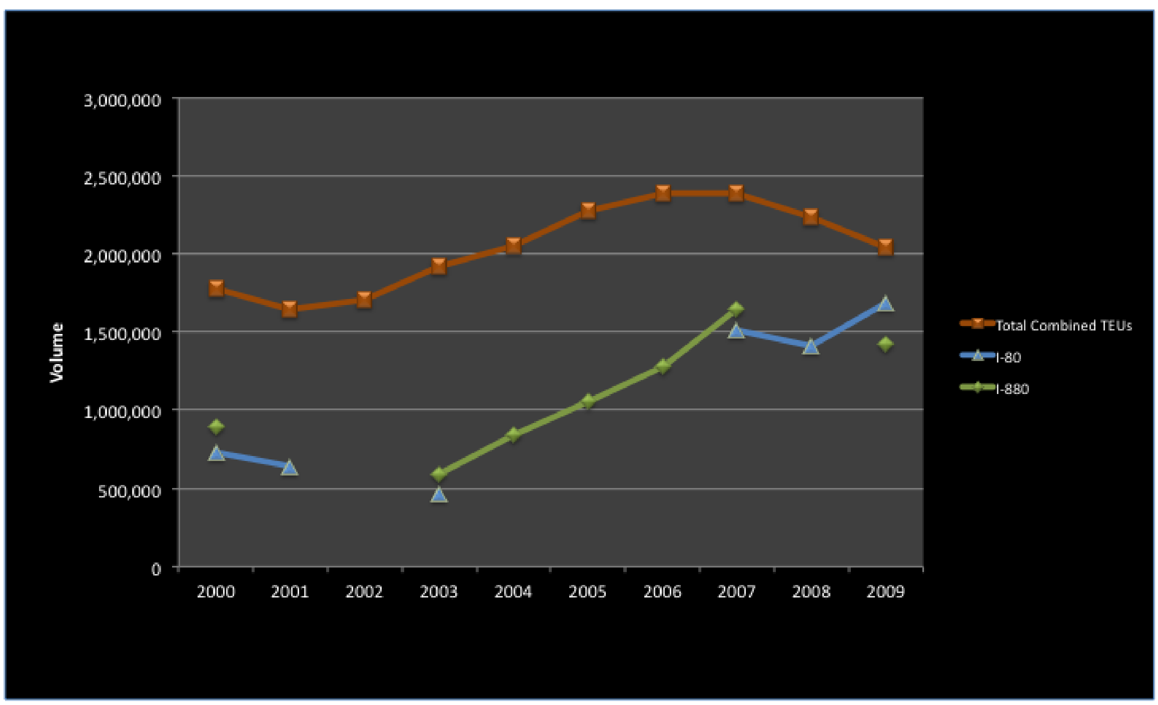
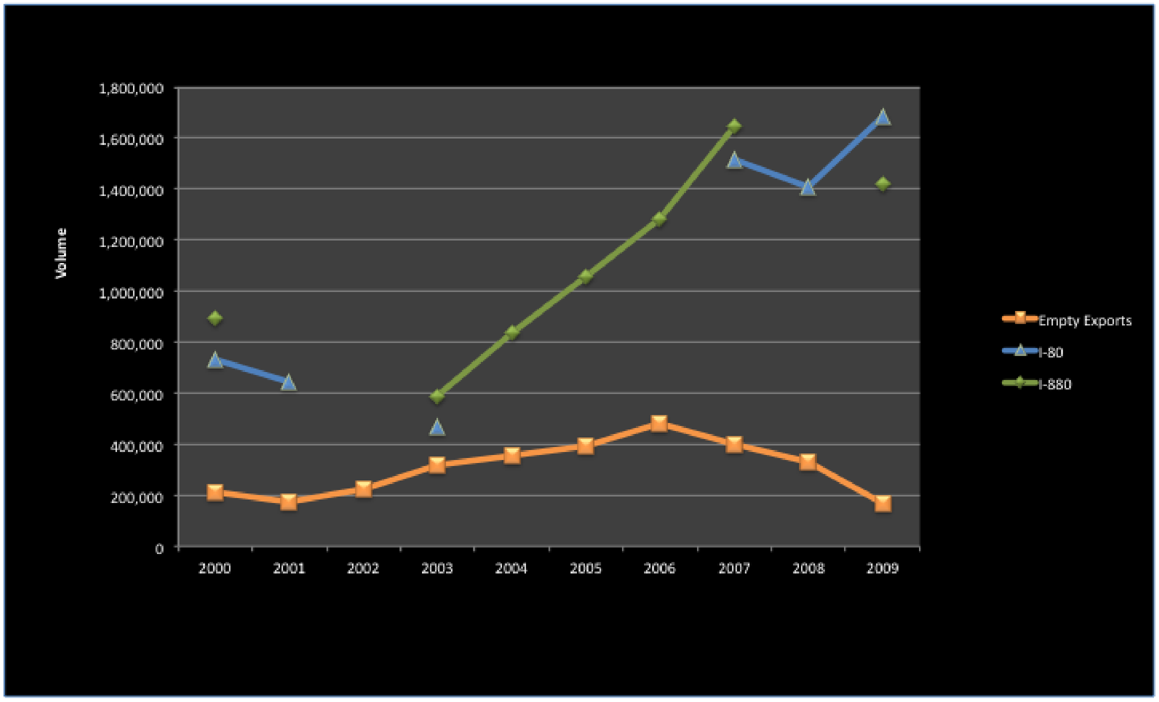


Figure 4-12. TEU-Qualified Trucks v. Empty Export TEUs, 2000-2009



4.3. Inferred Results

4.3.1. Linear Regression Analysis

Statistical inference, through linear regression analysis, supplements descriptive statistics by testing variable relationships. Specific value ranges reveal the extent to which one variable may affect others. In linear regression, correlations develop in positive or negative directions (i.e., positive or negative slopes), yet correlations are not absolute cause-and-effect values. In interpreting linear regression graphs between AADTTs and TEU throughput categories, for example, values that lie between 0 and $\pm$ 1 "have no direct interpretation" (Healey, 2005, p. 404). However, the strength and direction of the correlative relationships can be described via gamma values (*r*) as in Table 4-2.

Table 4-2. Linear Regression Correlation Strength Values

Value	Strength
0.00 – 0.30	Weak
0.30 – 0.60	Moderate
0.60 < r	Strong

Source: Healey, 2005, p. 368, Table 14.2 *The Relationship Between the Value of Gamma and the Strength of the Relationship.*

The coefficient of determination r^2 "is the proportion of the total variation in Y attributable to or explained by X…r^2 indicates precisely the extent to which X helps us predict, understand, or explain Y" (Healey, 2005, p. 407); AADTT and TEU-Qualified Truck volumes represent Y values and TEUs represent X values in this study.

4.3.2. Elasticity Analysis

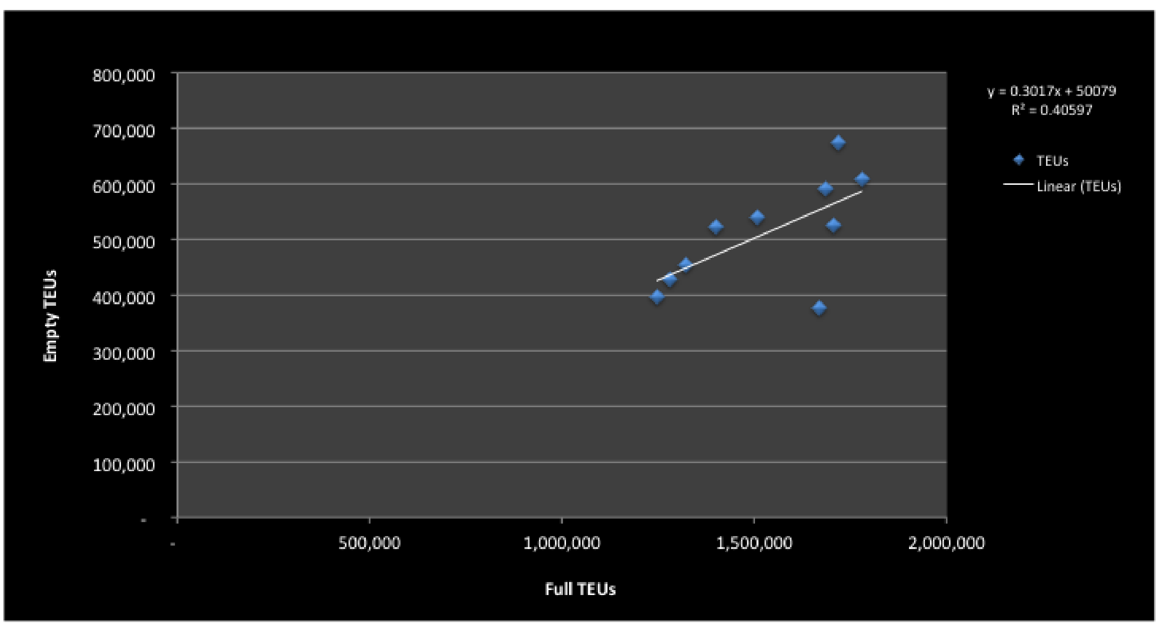
Elasticity values elicit effects of TEU volume variation on truck traffic volumes, especially those pertaining to Port of Oakland operations. Elasticity analysis was applied in three alternative scenarios:

- AADTTs v. AADTs
- AADTTs v. TEUs
- TEU-Classified Trucks v. TEUs

Container Throughput: Full v. Empty TEUs

Regression analysis performed within TEU throughput strata revealed positive correlation (Figure 4-13). Full and Empty TEUs exhibit a moderate relationship with a coefficient of determination of 0.40597. The ability to comparatively predict TEU flow based on container load is therefore also moderate.

Figure 4-13. Full v. Empty TEUs Regression Analysis, 2000-2009



AADTT v. AADTs

Data parameter inconsistencies between AADTT and AADT datasets led to reevaluation of study location methods along I-680. AADTT data along I-680 paradoxically did not exist for Sheridan Road, despite featuring AADT counts and a Mainline Census Station/WIM at that location in PeMS archives; AADTT data remains less detailed than AADT data. This is most evident in terms of Peak Hour classifications (Ahead, Back, Hourly, Monthly, etc), where AADTT data is limited to count locations with respect to milepost legs (Ahead, Back, Equal, at Intersection). Thus, AADTT counts combined two-way Ahead (A) and Equal (O) counts, to maintain consistency. Count locations, such as Ahead, Back, and Equal, refer to directional count methods. For example, Ahead (A) counts are taken for North and East locations relative to milepost count locations (Caltrans, 2010, p. v.). Back leg counts were less reliable in the AADTT data collection, as they were not taken at I-880 Industrial Parkway.

AADTT versus AADT volumes show strong correlations on I-680 and I-880, but moderate correlation on I-80 (Table 4-3). AADTT volumes are elastic with respect to AADTs along all corridors. Because of small shares of truck traffic on I-80, the effects of increases in total traffic register higher responses in truck volumes.

Table 4-3. AADTT v. AADT Volume Inferences

Location	
Coefficients of Determination	
I-880	1.00000
I-680	0.93929
I-80	0.48078
Elasticity	
I-880	1.000000
I-680	1.200000
I-80	2.394110

AADTT v. TEU Throughput

Relative AADTT volumes corresponded to TEU categories (Total Combined, Full, or Empty) uniquely. Regression analysis of each study corridor AADTT volumes and container throughput levels (Total Combined, Full, and Empty) exhibited positive correlations (Table 4-4). The range of coefficients of determination (r^2) was 0.20726, on I-80, to 0.80944, on I-680; the range indicates gamma (*r*) values within the study samples span weak, moderate and strong linear relationships between study variables. Results examining AADTT versus TEU trends reveal strong correlations at count locations on I-680 and I-880, based on values of coefficients of determination (r^2); correlations are weak for I-80.

Elasticity analysis using AADTT and TEU parameters varied depending on TEU category and corridor variables. AADTT volumes exhibited strong negative elasticity with regards to Empty TEU flow, whereas AADTT volumes were more likely to respond positively to Total Combined and Full container flows (Table 4-4). It is likely that AADTTs are more responsive to Total Combined and Full TEU movement for multiple reasons. Full TEUs comprise the majority of Total Combined TEU movements and are therefore more likely to be shipped daily, over the course of a year. Additionally, because Full TEUs comprise the majority of all TEU movements (81.58%), truck volume responsiveness to Total Combined TEUs is expected to be similar (Table 4-4).

Relative correlational values for AADTT versus TEU parameters show similar trends compared to AADTT versus AADT parameters. I-680 and I-880 continued to exhibit strong correlations against all TEU types, whereas the relationship between I-80 truck traffic and Empty TEUs are weak, then moderate, compared to Total Combined and

Full TEUs (Table 4-4). Elasticity analysis indicates relative reversal in value rankings: I-80 again revealed both greater positive elasticity and negative elasticity values, depending on TEU type. For Total Combined and Full TEU flows, I-80 AADTT volumes exhibited strong, positive elastic demand of 4.544260 and 7.875059, respectively. I-680 and I-880 AADTTs also produced certain elasticity equivalents. Yet, all three corridors exhibit very strong, negative elasticity with respect to Empty TEU volumes. Values indicate minimal impact of Empty TEUs on overall truck volumes at these count locations.

Table 4-4. AADTT v. TEU Volume Inferences

Location	Total Combined TEUs	Full TEUs	Empty TEUs
Coefficients of Determination			
I-880	0.79756	0.66216	0.69091
I-680	0.80944	0.70439	0.63389
I-80	0.44936	0.47702	0.20726
Elasticities			
I-880	3.034803	5.259219	-3.436576
I-680	1.630641	2.825849	-1.846518
I-80	4.544260	7.875059	-5.145867

Table 4-5. Full TEU Throughput Proportion of Total Combined TEUs, 2000-2009

	Full TEUs	Total Combined TEUs	Proportion
2000	1,322,379	1,776,922	74.42%
2001	1,245,347	1,643,585	75.77%
2002	1,279,767	1,707,827	74.94%
2003	1,398,958	1,923,104	72.74%
2004	1,508,030	2,047,504	73.65%
2005	1,682,837	2,273,990	74.00%
2006	1,717,923	2,391,745	71.83%
2007	1,779,917	2,387,911	74.54%
2008	1,707,104	2,233,533	76.43%
2009	1,668,383	2,045,211	81.58%

TEU-Qualified Trucks v. TEUs

Incomplete Vehicle Classification data sets in PeMS prompted adjusted elasticity analysis parameters for comparing TEU-Classified Truck and TEU volumes. Lack of complete 10-year TEU-Qualified Truck data would likely produce error in summed elasticity values for the entire study period. Instead, elasticity was calculated per available, individual study year due to a limited available drayage sample in PeMS. TEU-Qualified Truck data availability is tabulated in Table 4-6.

Inferred results regarding TEU flow effects on detailed Port-specific truck classes exhibit the strongest observed values for predicting Port activity impacts on truck volumes. However, results for this parameter were conclusive based only on I-80 and I-880 data; I-680 data was inconclusive based on the availability of just one data point, which existed for the year 2006.

Correlational and elasticity values are notably larger for I-80, when compared to previous parameter settings. It is now established that TEU-Qualified Trucks volumes on

I-80 maintained a strong relationship to TEU volumes, regardless of container load type. I-880 also produced elevated correlations over AADTT parameters, especially with regards to Full TEU loads (r^2= 0.9112). Elasticity for both observable corridors exhibit very positive values for Total Combined and Full container loads, but remained negatively elastic toward Empty loads (Table 4-7). The values herein imply that Full TEU volumes are more indicative of corresponding truck traffic. Furthermore, given that Full TEUs naturally ensconce greater weights, ESALs can be inferred to be greater for Full TEU volumes, thus impacting highway pavement surfaces more often.

Table 4-6. TEU-Qualified Truck Parameters

Location	Data Years Available (TEU-Qualified Trucks)
I-80 @ PINOLE (Appian Way)	2000, 2001, 2003, 2007-2009
I-680 @ SUNOL (Sheridan Road Interchange)	
I-880 @ HAYWARD (Industrial Parkway)	2000, 2003-2007, 2009

Table 4-7. TEU-Qualified Trucks v. TEU Inferences

Location	Total Combined TEUs	Ful TEUs	Empty TEUs
Coefficients of Determination			
I-880	0.8871	0.9112	0.8032
I-680	n/a	n/a	n/a
I-80	0.8224	0.7657	0.9038
Elasticities			
I-880	3.034803	5.259219	-3.436576
I-680	n/a	n/a	n/a
I-80	4.544260	7.875059	-5.145867

4.4. Pavement Impact Correlations

4.4.1. How Linear Regression & Elasticity Analyses Inform Pavement Impacts

Regression trends established correlations between container flows through the Port and truck volumes within the study area. Elasticity calculations tested the extent to which trucking volumes change with respect to TEU volume changes, in one percent increments. The elasticity of truck volumes with respect to TEU flows can help predict stress levels exerted on pavement by port TEU flows. The elasticity gauge thus informs infrastructure impacts.

Demand for trucking produces certain ramifications for pavement conditions. As pavement conditions deteriorate, multiple users are affected, maintenance programs become potentially stressed, and future freight network efficiency may diminish. There exists incentive to continue high trucking volumes for goods movement. Increasing economies of scale in overland freight distribution has consistently been reflected in decreasing unit costs of freight transportation (Hutchinson, 1990, p. 1). Since AADTT levels remained elevated over the course of 10 years - as did general AADTs - along study corridors, increased pavement stress is likely due to overall greater traffic volumes at sampled sites. Numerous studies conclude truck traffic incurs exponentially greater roadway damage potential (Bai et al., 2009; Hutchinson, 1990; MTC, 2004; Salama, Chatti, & Lyles, 2006). It is ascertained that increasing AADTT and TEU-Qualified Truck volumes produce exponentially greater roadway stress.

4.4.2. Estimation of Port Cargo Hauling Impact on Pavement

Pavement impacts of truck traffic, with emphasis on TEU-Qualified Truck volumes, are estimated with the Traffic Index (TI) formula in the Caltrans Highway Design Manual (CA HDM). The TI is a function of equivalent single axle loads (ESALs) and Lane Distribution Factor (LDF). To determine LDFs, lane configurations at each Census Station/WIM location were studied, in order to apply appropriate factor values per lane. Factor values represent numerical weights given to lanes more likely to be traveled by trucks (CA HDM, 2009, p. 610-5). For example, 0.8 (or 80%) is assigned to the two right lanes in each direction of a bi-directional eight-lane highway. Each corridor count location contains an 8-lane bi-directional roadway configuration, with the exception of I-880 at Industrial Parkway, which also contains a fifth High-Occupancy Vehicle (HOV) lane. However, per California Driver Handbook (2011), HOVs are reserved for carpools, buses, motorcycles, or decaled low-emission vehicles, so have negligible LDF value.

Total ESAL values were calculated based on TEU-Qualified Truck volumes, which are disaggregated by axle groups. For cumulative subsets, such as the " > 4 axle" class, a 3-axle average was applied to account for two to four axle range in that subset. ESAL values are based on 18-kip constants, per CA HDM standards, where 1 kip is approximately 1000 pounds (CA HDM, 2009, Foreword p. c). A TI value is then applied to ascertain minimum pavement construction standards. Acquired values were then compared to ESAL constants established by Caltrans. TI calculations are based on 10-year constants, to reflect the study period. ESAL Constants exist for 2, 3, and 4-axle classifications. The 10-year constant was calibrated using a 3-axle average for that truck type range (1,840 ESALs). LDFs were accounted using the TI formula (Figure 4-14). For purposes of clarification, ESAL constants represent average weight-bearing values for truckloads. Truckloads, even for similar axle values, may differ significantly, depending on cargo type (i.e., two 4-axle trucks could encumber 4-axle impacts and 8-axle equivalent impacts, respectively, if the latter is more heavily loaded). The ESAL is therefore an estimation established by the CA HDM.

Figure 4-14. TI Formula

$$TI = 9.0 \times \left(\frac{(ESAL \times LDF)}{10^6} \right)^{0.119}$$

Where:

TI = Traffic Index

ESAL = Total number of cumulative 18-kip Equivalent Single Axle Loads

LDF = Lane Distribution Factor (see Table 613.3B)

Source: Caltrans, 2009, Highway Design Manual, p. 610-5.

Cumulative ESALs for the 5-axle ST class exceeded the maximum 303,000,000 (17.5 TI) in the CA HDM ESAL-to-TI conversion table. 5-axle truck class consistently exceeded 17.5 on the TI Index (Table 4-7). 5-axle drayage was also the overwhelming majority of observed truck traffic, an aspect with considerable ramifications for pavement distress; a sample table shows the lowest proportion of 5-axle trucks relative to overall TEU-Qualified Truck volumes, to illustrate the minimum scale of 5-axle truck prevalence (Table 4-8). The TI formula was therefore applied to all other cumulative ESAL values, for consistency. Multiplying 10-year ESAL constants by stratified TEU-Qualified Truck axle groups produced Average TI per Lane per Year values ranging from approximately

14.8 to 16.2 as shown in Table 4-6. LDFs are naturally greater for roadway lanes 3 and 4, at 0.8, indicating an 80% weight given to those lanes with respect to truck traffic, as previously reported. Additionally, due to the propensity of slower heavy vehicle traffic travel in the right-most highway lanes, average TI values per lane per year more closely resemble TI values calculated for lanes nearer to the right-side shoulder versus those nearer to the median.

Average TI values show that truck volumes produce greatest corresponding pavement impacts on I-880, although comparable impacts are deduced from I-80 averages (Table 4-9). Pavement impacts on I-80 are noticeably larger in the latter stages of the study period, based on six observable data points (Table 4-10). Increasing TI values, as function of increasing ESALs, indicates increasing pavement impacts as cargo and truck traffic also increased from 2000-2009.One-year data along I-680 leads to minimal longitudinal conclusions, although the lower average TI value for 2006 reflects lower overall AADTT and TEU-Qualified volumes along the corridor.

Table 4-8. Average 5-Axle TI for All Corridors, 2000-2009

	I-80	I-680	I-880
2000	21.6371		21.9109
2001	21.2947		
2002			
2003	20.5353		20.9783
2004			21.8596
2005			22.5180
2006		20.0714	
2007	23.7215		23.0333
2008	23.5583		23.7541
2009	24.0688		23.3786
Difference	***2.4318***	***-***	***1.4677***
% Change	***11.24%***	***-***	***6.70%***
Average	***22.4693***	***20.0714***	***22.4904***
Overall Avg.		***21.6770***	

Table 4-9. Minimum 5-Axle ST Proportion of TEU-Qualified Trucks (Sample: I-880, 2009)

Vehicle Class	# Vehicles	% Total
Motorcycles	337680	0.5
Cars	49822055	77.8
2 Axle, 4T SU	10264147	16
Bus	84074	0.1
2 Axle,6T SU	1804967	2.8
3 Axle SU	182846	0.3
4+ Axle SU	6788	0
< 4 Axle ST	254366	0.4
5 Axle ST	1074380	1.7
6+ Axle ST	8570	0
< 5 Axle MT	74686	0.1
6 Axle MT	10887	0
7+ Axle MT	895	0
User-Def	54799	0.1
Unknown	47794	0.1

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 09

Source: Caltrans, 2011, Performance Management Systems.

Table 4-10. Average TI Per Lane Per Year for All Corridors, 2000-2009

	I-80	I-680	I-880
2000	14.8170		15.2397
2001	14.6508		
2002			
2003	14.1227		14.4393
2004			15.0351
2005			15.3676
2006		14.0137	
2007	16.0824		15.6696
2008	15.8773		16.0979
2009	16.2236		15.6634
Difference	*1.4066*	*-*	*0.4237*
% Change	*9.49%*	*-*	*2.78%*
Average	*15.2956*	*14.0137*	*15.3589*
Overall Avg.		*14.8894*	

4.4.3. Types of Pavement Impacts

Consequences of pavement deterioration ultimately lead to damaged roadway surfaces if rehabilitation is inadequate. Pavement damage can manifest in multiple ways, according to type and duration of inflicting forces. In addition to traffic loading, other factors such as weather, soil conditions, and asphalt hardening contribute to roadway damage and can decrease pavement design life spans. The MTC Pavement Condition-Index Distress Identification Manual for Asphalt and Surface Treatment Pavements (PCI-Manual) articulates guidelines to identify damaged roadway surfaces. The PCI Manual includes examples of pavement damage likely to occur in the event of traffic loading, which pertains to drayage traffic impacts.

The PCI Manual identifies specific, visible roadway damage categories. Pavement distress types are listed below:

- Alligator cracking
- Block cracking
- Distortions
- Longitudinal and transverse cracking
- Patching and utility cut patching
- Rutting and depressions
- Weathering and raveling

Source: MTC, PCI Manual, 1986, p. iv.

Of the designated pavement distress categories, alligator cracking, rutting and depressions, and raveling are most commonly identified with traffic loading. Raveling is especially corroborated with tracked vehicles (MTC PCI Manual, 1986, p. 2), such as trailers. Figures 4-16 through 4-18 visualize specific stress-related roadway damage that may occur as a result of continual exposure to traffic impacts.

Figure 4-15. Alligator Cracking (High Severity)

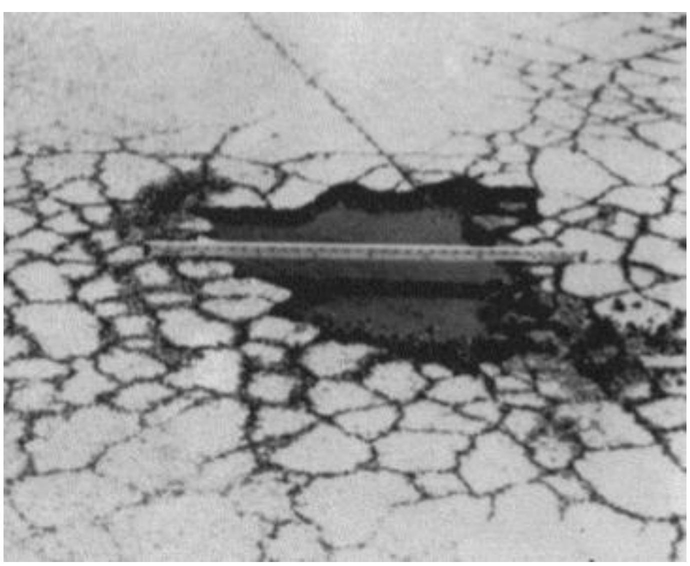


Figure 4-16. Rutting & Depression (High Severity)

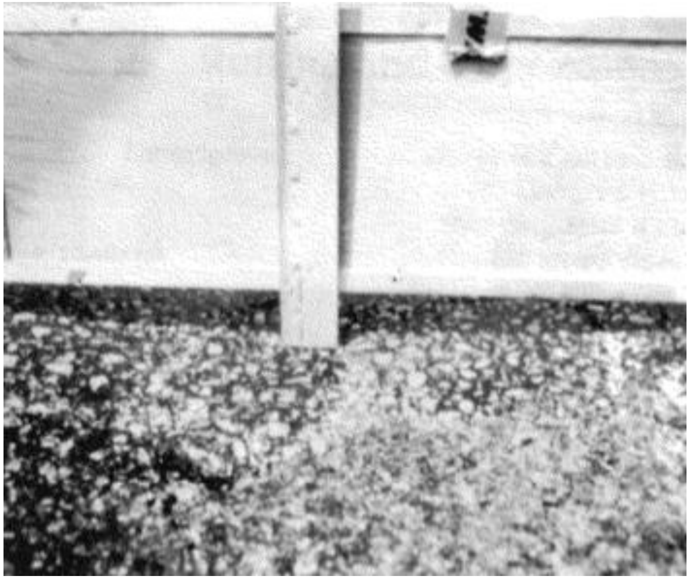
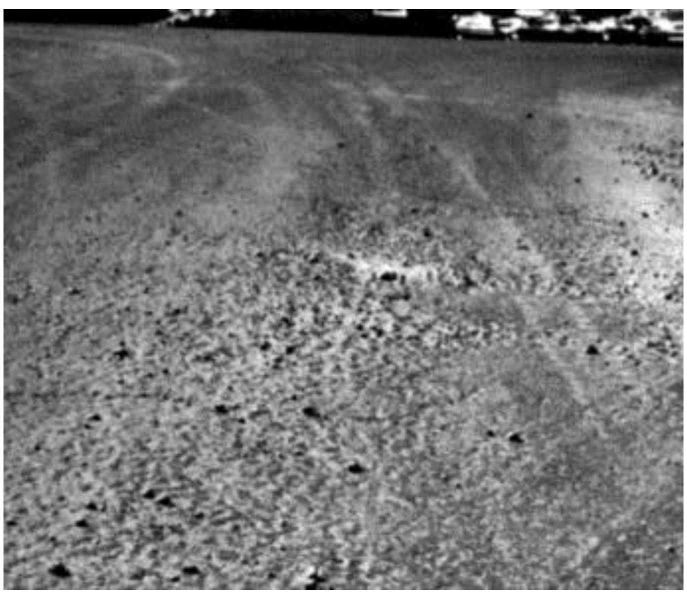


Figure 4-17. Weathering & Raveling (Medium Severity)



Source: Metropolitan Transportation Commission, 1986, PCI Manual.

4.5. Conclusion

Truck and auto traffic trends were similar for all study corridors. Sample volumes for both trucks and autos increased by the end of the decade, from 2000 to 2009.

Increasing volumes for both vehicular modes implies advancing pavement deterioration due to more frequent surface exposure to vehicular impacts. Truck volumes along all study corridors exhibited positive correlations with respect to container movement, regardless of Full or Empty status. Positive drayage and container correlations indicate that a relationship existed between TEU throughput activity and truck movement along study corridors throughout the study period. The results generally indicate that Port of Oakland container throughput is predictive of truck traffic along proximate freight corridors.

Continual pavement stress is likely to occur as exposure to damaging load forces increase. Vehicular traffic on all study corridors, especially drayage, increased over the course of the study period. TI calculations confirm average pavement stress levels existed near the maximum criteria for the TI Index spectrum for each observable year; 5-axle trucks were particularly prevalent and exceed maximum TI Index values for every observable year. Full TEU volumes also exceeded Empty TEUs, which exacerbate stress levels through increased ESAL values; a truck hauling a loaded TEU will inflict more damage than unloaded trucks.

Sound roadway conditions contribute positively to traffic networks by reducing vehicle wear and tear, maximizing intended design speeds, and minimizing risks associated with surface deterioration, which can negatively affect vehicle handling capabilities. However, as TI Index values increasingly approach maximum serviceability standards on study corridors, traffic flow – particularly goods movement – may face simultaneous inefficiencies due to adverse infrastructure conditions. Policies addressing freight corridor pavement conditions and measures to improve network performance are necessary to maintain the Port of Oakland's goals to uphold global logistical competitiveness, in addition to preserving regional infrastructure serviceability. Policy considerations to this effect are discussed in the ensuing chapter, which explores applicable policy directions for enhanced freight circulation near the Port of Oakland concurrent with sustainable regional infrastructure accommodations.

Chapter 5. Policy Considerations

5.1. Introduction

The Alameda County Congestion Management Agency's (ACCMA) 2010 Countywide Truck Travel Demand Model report noted, "…the need for infrastructure improvements to facilitate goods movement far outpaces available funding" (1-1). This study's results show that increasing Port activity in terms of container cargo correlated with the volume of truck traffic since the turn of the 21st century (see Chapter 4: Results & Analysis). Average and cumulative traffic index (TI) values along all study corridors trended upward and approached maximum TI values indicated in the California Highway Design Manual (CA HDM, 2009). The ACCMA Countywide Truck Travel Demand Model also forecasts between 40-60% increase in truck traffic along with more than 100% growth in container cargo throughput by 2035 (p. 7-1-7-8). Evidence suggests that, in addition to potential congestion and air quality concerns, truck-serving corridors near the Port of Oakland have, and will continue, to endure significant pavement stress as a result of increased truck travel demand.

Increasing freight demand has ensured that facility expansion is inevitable at the Port of Oakland, concurrent with increasing demand for goods. Several factors indicate Port policies intend to satiate growing freight demand in the Bay Area. Marine channel dredging is ongoing to accommodate 50-foot drafts of ever-larger container-laden ships and purchase of additional land from the defunct Oakland Army Base has been completed (Port of Oakland, 2011). Combined with overall growth in container cargo since the turn of the 21st century, aforementioned infrastructure improvements are testament to the Port's intent to maximize competitiveness and the ability to optimize goods movement efficiency.

The Port simultaneously recognizes significant environmental impacts borne of increasing freight demand. For example, in 2009, the Port introduced a Comprehensive Truck Management Program (CTMP) designed, in part, to mitigate excessive truck emissions as a result of idling and other freight forwarding activities (Port of Oakland, 2011). However, resolutions for freight corridor infrastructure impacts, in terms of roadway conditions and serviceability, remain at large. In this chapter, feasible policy directions are explored, to mitigate freight truck impacts on freight corridor pavements in the study area.

5.1.1. Chapter Contents

Study results can inform policy considerations for future Port operations and the Bay Area freight network in entirety. Policy considerations draw from the following sources:

- Brief review of study results and analyses
- Literature review of freight truck impact mitigation strategies
- Existing professional report policy conclusions
- Statutory and legal environment of Port operations, as part of feasibility study of policy implementation strategies
- Existing Port policies and programs addressing drayage impacts on roadways

In particular, the statutory context surrounding the Port of Oakland, including regulations and limitations, are examined in light of feasible policy directions related to freight corridor infrastructure support and stress mitigation.

5.1.2. Review of Key Study Findings

Except where noted, findings reflect trends occurring over the course of the entire study period, 2000 to 2009. Similarly, corridor findings reflect results specific to Census Station/WIM count locations along respective corridors. Findings may be referenced in Chapter 4: Results & Analysis.

<u>Container Throughput</u>

- Overall maritime container volume throughput increased
- An upward trend in container throughput persisted through 2006 before beginning a downward digression through 2009
- The Port maintained an export-dominant trend, except in 2006, when more containers were imported than exported
- For the years 2006-2009, inverse relationships exist between Full exports (upward) and imports (downward) and between Empty exports (downward) and imports (upward). This can be read another way, to mean that Full exports and Empty imports were growing while Full imports and Empty exports declined during the last four years of the study period; Empty exports also digressed more than 50% during that time

AADTT v. AADTs

- Truck volumes trended in similar pattern to general automobile traffic
- The I-680 corridor featured the largest truck mode share along the route, at 9.20%, whereas I-880 truck mode share was 5.90%, and I-80 revealed the smallest truck mode share of 4.18%
- Linear regression correlations varied from moderate to strong: I-80 (0.440); I-880 (0.798); I-680 (0.809)
- Positive elasticity exists on all routes: I-880 (1.0); I-680 (1.2); I-80 (2.4)
- Extremely positive elasticity on I-80 implies strongest truck mode utility, although positive elasticity across the board implies routes are for container shipment

AADTT v. TEUs

- Overall growth in container cargo (measured in TEUs) outpaced AADTT growth, which implies larger sizes of individual containers
- However, as Total Combined TEUs declined, so did AADTT volumes
- AADTT volumes correlate strongly with TEU flows with the exception of I-80, where weak (Empty TEUs) and moderate (Total Combined, Full TEUs) linear regression relationships exist
- Extremely positive elasticity with respect to Total Combined and Full TEU flows exists on all routes; I-80 is strongest at 7.88 (Full) and 4.54 (Total Combined)
- AADTT versus Empty TEUs exhibit extremely negative elasticity across all corridors; I-80 is the most negative elasticity against Empty TEUs

TEU-Qualified Trucks v. TEU Volumes

- Due to the availability of just a single data point (year), I-680 is basically moot in this portion of the study
- Compared to prior study parameters, linear regression correlations and elasticity values are strongest between TEU-Qualified Trucks versus TEU volumes
- Linear regression correlations between TEU-Qualified and Empty TEU flows buck previous trend of weak AADTT versus Empty TEU correlations; in fact, observable correlations are strong on I-80, at 0.90 and I-880, at 0.80.
- Minimum correlational value for both observable routes, I-80 and I-880, are a function of Full TEUs; I-80 correlation is 0.77 while I-880 correlation is highest at 0.91.
- However, Empty TEU elasticity maintains trend exhibited by AADTT versus TEUs: very negative elasticity, such that a 1% change in Empty TEU volumes dictates an inverse 1% change for TEU-Qualified truck volumes.

Traffic Index (TI) Calculations

- As with TEU-Qualified Trucks versus TEU parameter comparisons, the availability of just a single data point (year) on I-680 basically renders that corridor moot in this portion of the study
- Observable, average TI index values *per lane per year* grew for both I-80 and I-880 routes
- Average TI index values per lane per year was 14.9 across all corridors; this

approaches the TI Index maximum of 17.5, indicating relatively high roadway pavement stress levels in the Study Area

- Observable, cumulative TI index values also grew for both I-80 and I-880

Overall Findings

- Imports report similar trends as truck traffic (AADTT & TEU-Qualified Trucks); Full TEU throughput trends are also inferred to mirror truck volumes, thus Full Imports – which have implications for inland distribution – report highly predictive shipment patterns.
- AADTT volumes v. TEU flows show strong relationships regarding Total Combined and Full TEUs and overall weak relationships and negative elasticity regarding Empty TEUs – thus, Full TEUs drive Total Combined correlations and elasticity values.

5.2. Policy Implications

According to the California Highway Design Manual (HDM), elevated TI values that approach the maximum of 17.5 may cause rapid roadway deterioration and compromise multiple aspects of highway travel, including:

- ride quality
- system and personal vehicle maintenance costs
- roadway user costs, including lost time
- safety concerns
- underutilized design speeds

- congestion

As study freight corridors simultaneously serve automobiles, adverse pavement conditions also negatively affect significant non-freight user populations. Existing literature on freight network policy address freight truck impacts, although pavement-specific impacts are typically secondary to congestion management studies, such as truck-only lanes, truck tolls, and intermodal facility placement, for example. Available policy literature is thus analyzed to determine applicability toward mitigating pavement stress in the Bay Area freight corridors.

5.3. Literature Review

Improving overland cargo distribution is an environmental, safety, and economic issue. Efficient movement of goods may mitigate escalating emissions from congestion and over-reliance on trucking by balancing freight modal splits. Congestion associated with overland freight shipping also poses safety and other risks, both for road users and neighboring communities exposed to emissions, noise, and vehicular flow. Additionally, the Port of Oakland – and the Bay Area region – stands to benefit from infrastructure and multimodal capabilities that promote rapid goods movement at economies of scale.

5.3.1. Overview of Policy Directions in Literature

General drayage traffic impacts on transportation networks is a national concern. Douglas (2003) discusses broad policy directions in a National Cooperative Highway Research Program (NCHRP) study. The study focuses on adverse effects of growing freight transport via highways. National freight truck policies were studied by surveying various stakeholders, including state DOTs and MPOs, regarding existence, feasibility, and preferences of certain policy directions. Categorical policy directions highlighted are:

- Improved Highway Design
- Roadway Facilities for Trucks
- Operational Strategies
- Signing
- Vehicle Size & Configuration
- Code Enforcement and Compliance
- Intelligent Transportation Systems
- Investments in Alternative Infrastructure

Source: Douglas, 2003, p. 18-22.

Fischer, Hicks, and Cartwright (2006) also emphasize specific policies encompassing drayage management strategies in a case study of the combined Port of Los Angeles and Port of Long Beach freight terminal complex. Potential implementation tools studied include:

- Virtual Container Yard (VCY)
- Extended Gate Hours
- Shuttle Trains
- Near-Dock Rail

A summary of available literature elicits patterns in policy conclusions. Pavement impacts are indirectly addressed in most studies as study emphases tend toward congestion mitigation solutions. Holguin-Veras (2008) and Sathaye, Harley, and Madanat

(2009) have researched the effects of alternative freight delivery hours as a means to reduce peak hour congestion. Separate freight truck facilities are also posited in academia. Poole, Jr. (2009) discusses comprehensive factors contributing to appropriate truck-only lane dedication, while Fischer, Ahanotu, and Waliszewski (2003) focus on efforts in Southern California to implement truck-only lanes.

Economic policies supplement logistical and infrastructural policies. The merits of truck-specific tolling facilities have been evaluated in this respect. Multiple studies indicate freight pricing can induce truck traffic demand shifts, but are more effective when combined with complementary policies (Holguin-Veras et al., 2003; Holguin-Veras, 2010; Kawamura, 2003).

Policy discussions most directly addressing pavement impacts center on freight modal shifts. Rail and inland water transport are commonly cited as viable alternatives. In addition to reducing roadway congestion, truck-auto conflicts, and shortening of infrastructure lifespans, shipping economies of scale are enhanced (Bryan et al., 2007). Additionally, Stewart et al. (2008) did examine pavement impacts resulting from freight rail to trucking modal shifts in the Great Lakes region. Holguin-Veras et al. (2003) also utilize economic and fiscal feasibility studies of heavy-truck lane tolls with Highway-Design Standards Model (HDSM) parameters built in, to gauge pavement impacts.

5.3.2. On Alternative Drayage/Delivery Hours

Shifting container throughput operation hours to off-peak times is one policy consideration for reducing pavement impacts. Holguin-Veras and Silas (2008) investigate the feasibility and effectiveness of off-peak hour deliveries in a case study featuring the Port Authority of New York-New Jersey. Several acknowledged obstacles to the off-hour delivery concept include additional costs assumed by receivers in order to accommodate such shipments (p. X). However, evidence strongly suggests off-hour deliveries would be preferable for carriers. It has been estimated that off-hour freight shipments can reduce carrier costs by 28% compared to regular hour shipments (Holguin-Veras, 2010, p. 6368, cited from Holguin-Veras, 2006).

Yet, as Holguin-Veras and Silas (2008) note, it is possible that off-hour deliveries could increase receiver costs, thereby negating potential impact mitigation incentives. It is also inconclusive as to whether impact levels would decrease in the long run, since total truck traffic may not diminish, but simply be striated over the course of working days. In fact, Fischer, Hicks, and Cartwright confirm that extended gate hours do not mitigate truck trips or truck VMT (p. 9).

5.3.3. On Separate Truck Facilities

Separate truck facilities may entail single or multiple highway lanes dedicated to truck travel. The effectiveness of dedicated truck facilities at reducing roadway impacts is considered a matter of efficiency. Fischer, Ahanotu, and Waliszewski (2003) focused on Southern California freight trucking conditions. They note that reliability is a major need for drayage operators (p. 75), a perception that is presumably significant to freight network participants in general.

Additional findings, based on truck lane simulations from Southern California Association of Governments' (SCAG) travel demand models have indicated more modest truck use projections due to the fact that carrier trip lengths are typically shorter than would fulfill the demand of long-range, systemic truck lane implementation (Fischer, Ahanotu, and Waliszewski, 2003, p. 75). However, benefits also include "incident management flexibility", where multiple truck lanes exist, in the event of a blocked lane (p. 75).

Dichotomous factors of multiple access points versus ubiquitous truck-only lanes tests the feasibility of separate truck lane facilities. Increased access points imply additional ROW acquisition costs, on top of proposed truck lane infrastructure costs. Yet, in very congested origin and destination (O-D) networks, truck lanes may attain feasibility. In fact, safety considerations may be more significant for purposes of separating truck-auto traffic, rather than purely congestion (Fischer, Ahanotu, and Waliszewski, 2003, p. 78).

Although degrading safety conditions may be derived as a function of decreasing pavement quality, it remains questionable as to whether pavement impacts are a deciding impetus for truck lane facility implementation. It is assumed drayage traffic will impact pavement on separate facilities regardless, unless alternative materials or modes are increasingly utilized.

5.3.4. On Truck Tolling/Congestion Pricing

Congestion pricing is a specific policy direction intended to alleviate oversaturated roadways through temporally-adjusted tolling prices. Indirect effects on pavement stress alleviation are possible as well, as a function of potential reduced peak loads traversing freight corridors. Off-hour freight distribution systems are also implicated in this conversation, although such arrangements are more sector-specific and based on inter-agent collaboration, as opposed to public roadway fees like truck-specific tolls.

Holguin-Veras et al. (2003) produced favorable findings regarding truck-tolling facilities. Study parameters also included heavy-truck (HT) lane placement, which encompasses separate truck facilities. The results are especially significant because the authors incorporated pavement impact analysis with HDSM parameters. Overall system costs are found to be lower due to severe pavement damage occurring in isolated truck lanes. In fact, Holguin-Veras et al. (2003) assert that “increased gross weight limits and truck sizes” are feasible for separate tolling facilities since roadway stress is isolated and costs recouped through travel charges (p. 66). Even while roadway serviceability ratings are noted to decrease during the study simulation, remedies for infrastructural impacts are reliant on positive return on investment (ROI). Additional findings assume that larger trucks running less frequently would occur with the presence of HT Lanes (p. 70), thus offsetting significant pavement deterioration.

5.3.5. On Modal Shifts to Rail

Bryan et al. (2007) developed NCHRP Report 586, on rail freight policy relative to roadway congestion. The report provides a comprehensive, authoritative discussion of rail freight history, current conditions, and future policy directives as guidelines for managing freight networks. The report is especially applicable to urban and regional contexts, such as drayage operations extending from the Port of Oakland.

It is established that truckloads, especially in urban areas, are usually quicker and more reliable (Bryan et al., 2007, p. 6). In fact, rail competitiveness in urban and regional areas (i.e., short-haul distances) is virtually moot compared to trucking. Average truck shipment distance is less than 300 miles while average rail shipments are approximately 500 miles (Bryan et al., 2007, p. 7).

Yet, railroads are more fuel-efficient than trucks, due to more efficient infrastructure factors, such as steel wheel and rail rolling friction and more forgiving incline and decline grades along rail routes (Bryan et al., 2007, p. 10). Such economic and infrastructural efficiency could alleviate pavement deterioration, which is detrimental to the environment, vehicle operating costs, safety, and logistics.

5.3.6. On Supply Chain Alternatives

Logistical alternatives may entail alleviating pavement impacts by optimizing freight distribution networks, diverting freight to other modes, or increasing technological influence in freight movement. Intermodal distribution centers may minimize cargo transfer time losses by combining multimodal operations at particular network nodes where truck and rail systems converge. Smaller maritime vessels capable of navigating inland waterways, in addition to rail, represent alternative modes. Intelligent transportation systems (ITS) deployment may aid freight network efficiency through real-time traffic condition updates and routing functions.

Bryan et al. (2007) identifies three major benefits to relocating intermodal cargo transfers to inland ports:

- Reduce truck traffic congestion near main port
- Reduce rail/roadway intersection delays
- Removes constraints on port expansion that are attributable to truck capacity
- limitations

Source: Bryan et al., 2007, p. 55.

Bryan et al. (2007) conclude that intermodal facilities particularly enhance freight rail transport and can improve overall freight distribution networks. Such advantages can be manifested in two ways: 1) intermodal facilities promote rail shuttling from various points throughout the network and may reduce drayage VMT and ton-miles and 2) required land area is reduced (p. 14). A dedicated intermodal facility essentially transfers converging freight traffic to a different location and retains trip generation characteristics of a major freight distribution source, such as a seaport. Intermodal distribution centers may engender more competitive freight rail systems and incentivize more future implementation.

5.4. Statutory & Legal Context of the Port

Available literature reveals a variety of policy directions to mitigate freight truck impacts on regional study corridors. Some policy ideas directly address pavement impacts. Yet, most indirectly address the study issue through congestion mitigation tactics, and specific programs therein, such as delivery schedule adjustments, tolling, dedicated facility construction, and modal shifts. Each policy option entails potential for implementation in the Bay Area, but the extent to which such policies can be realized is governed primarily by codified state and regional statutes. This section covers state and regional statutory and legal frameworks concerning infrastructure improvements, including construction, fiscal, and maintenance responsibilities. Applicability of reviewed policy directions subsequently follow.

5.4.1. Authoritative Codes & Documents

Federal Highway Administration (FHWA) Federal-Aid Policy Guide

Study corridors are Interstate highways that are segments of the National Highway System. Interstate highways function as vehicular, mobility-enhancement facilities for the movement of people and goods throughout the U.S. Interstate highways are indubitably critical to drayage operations, as trucks are able to utilize higher design speeds relative to arterial and local street facilities, thus increasing shipment speed and efficiency. However, national and regional truck freight traffic trends show that congestion is becoming increasingly common (ACCMA, 2010; Bryan et al., 2007; FHWA, 2011; MTC, 2004). Escalating freight truck traffic congestion is evidenced by increasing freight VMT and ton-miles traveled (ACCMA, 2010; MTC, 2004). As study findings have correlated, increasing truck traffic implies advancing pavement deterioration and a need to remedy infrastructure conditions to ensure continued logistical and economic competitiveness.

An understanding of policies governing Federal transportation facilities provides insight into institutional capabilities regarding infrastructure improvements near the Port of Oakland. The California Department of Transportation (Caltrans) owns and manages Interstate highways located within The State’s jurisdictional boundaries (Caltrans, 2011; FHWA, 2011), yet federal statutes govern intended modifications to Interstate highways. The Federal Highway Administration (FHWA) contains a Federal-Aid Policy Guide delineating appropriate procedures to act on highway improvements, such as those resulting from pavement damage. FHWA Federal-Aid Policy Guide, Section 470.111

specifically states “Proposals for system actions on the Interstate System shall include a route description and a statement of justification”.

California Streets/Highways code

The FHWA notes that Caltrans is primary owner and operator of Interstate highways within state boundaries. The California Streets & Highways code provides statutory guidance in this respect. Particular sections of interest, related to potential pavement impacts, delineate mechanisms available to remedy deteriorating roadway surfaces. Section 253.1 identifies study routes I-80, I-680, and I-880 as segments under the California Freeway and Expressway System. In this context, Section 251 declares the State’s intent to rehabilitate “relative deficiencies and the needs of traffic service” of the State Highway System and the State Freeway and Expressway System. A summary of applicable statutes within the Streets & Highways code entails policy development considerations for future Port efforts:

- **Division 1., Ch. 3 The Care and Protection of State Highways**

Sections 676 through 678 focus on delegation of power by the state and initial funding mechanisms to support State Highway conditions.

Section 676: A city may assume state authority, except approval power, to any State highway, although the state may also renege such authority.

Section 677; A bond payment is required for permit application for State highway improvements.

Section 678; A bond is not required, however, if a public highway is already under regional or local authority. Additionally, permits for improvement are ministerial (by right), but must conform to State provisions on applications. Failure to comply shall yield not more than $20,000 in bonds.

- **Division 3., Ch. 4.9 Port-Related Cargo**

Section 2196: Directs the Port of Los Angeles and Port of Long Beach to "evaluate changes to the goods movement network" and to report on their respective compliance with federal, state, and local goals.

Section 2196.1: Additional direction provided to the ports of Los Angeles and Long Beach, "to the extent practicable, shall provide the statistical data on imports and exports...on or before January 31, 2006…through 2008".

- **Division 16, Ch. 2 Organization and Reorganization of Districts**

Section 25025: Multiple counties may comprise districts for the purpose of improving public highways.

Section 25026: Any county board of supervisors may initiate public highway improvement and right of way acquisitions within the public's interest.

- **Division 16, Ch. 3 General Powers of Districts**

Section 25050: Reasserts district board of directors (via Section 25025) authority to improve public highways, issue bonds and taxes on property within district boundaries

Source: State of California, 2011, Streets and Highways Code.

The California Streets & Highways code allows for certain delegating powers to be conferred upon regional and local governing bodies. Initiation of public highway improvements apparently rests with counties and cities affected by specific routes and associated conditions. Division 3, Chapter 4.9 Port-Related Cargo is of note, due to its specificity and exclusion of other significant state ports.

5.4.2. Port of Oakland Statutory Context

Knowledge of the Port of Oakland's statutory and legal framework informs the extent, and limitations, of power to influence the Port's primary function as a major seaport. The Port of Oakland, like the City of Oakland itself, is a public entity. The Port Department, a subsidiary of the City of Oakland, was established in Article VII of the original Charter of the City of Oakland (the "Charter"), in 1968. The Article VII ordinance expresses the Port's structural makeup, statutory procedures, responsibilities, and limitations on authority. A seven-member Board of Port Commissioners (the "Board") - nominated by the City Mayor and appointed by the City Council - oversees Port operations (§701). As expressed in §706, the Board "shall have the complete and exclusive power [to act] for and on behalf of the City" (The Charter of the City of Oakland, 1969, Article VII).

Port Infrastructure Jurisdiction

Statutory limitations at the Port encompass infrastructure improvements. The Charter outlines jurisdictional authority over public streets, air, land, and water facilities, and properties specific to the Port. Therefore, infrastructural improvements related to Port operations are limited to areas owned by the Port. In general, infrastructure maintenance emphasizes maritime facility improvement, such as those to waterfront property and waterway channels.

Financing Port Operations

Sections 715-721 address fiscal powers bestowed upon the Port. According to the Port website, "The Port funds its own operations. It receives no tax money from the city, and instead supports businesses that provide millions in tax revenue to the City of Oakland and the State of California." (Port of Oakland, 2011). However, Charter §716 specifically authorizes the Port to request "allocation or appropriation…of any funds raised or to be raised by tax levy or in any manner to be obtained from general revenues of the City, or shall request the incurring or payment of any financial obligation by the City for the Port's use and benefit…", although the Council also retains the right to reject such budget measures (Charter, 716, Amended Nov '88 and March '04).

General bond obligations may also be assumed by the City to finance Port operations. Section 718.1 authorizes periodical bonded indebtedness by the City, on behalf of the Port, for "acquisition, construction, or completion of any port facilities or improvements…including land, rights of way and air easements". Furthermore, the Board retains authority over bond proceeds (§718.1).

The Port also maintains a Harbor Maintenance Trust Fund (the "Fund"). Taxes levied on port customers support the Fund, which has attained a $5 billion surplus (Port of Oakland, 2011). Fund revenues are allocated specifically to "navigational maintenance and harbor improvements" (Port of Oakland, 2011). Improving maritime facilities for purposes of more efficient container vessel calls implicates increased overland freight distribution, to sustain goods demand. With future rail yard improvements pending, it is assumed drayage operations will continue to handle the large majority of containers and impact conditions in regional freight corridors.

5.5. Existing Port Policy Directions

The Port has initiated efforts to curb truck traffic impacts, although pavement-specific mitigation policies are lacking. Policies have been implemented through programs mainly emphasizing environmental concerns and congestion near port facilities; some are active while others remain conceptual.

5.5.1. Current Port of Oakland Policies & Programs

The Port of Oakland has and proposes to embark on policies to improve freight movement efficiency. Numerous programs have also been implemented to fulfill new policies. Port policies pertaining to container throughput directly affect multimodal operations and may relieve regional corridor pavement stress, thereby maintaining the expected design life of roadways impacted by container truck traffic. For this study, general policies influencing container throughput operations are analyzed separately from policies and programs specifically addressing regional truck pavement impacts.

General

Port of Oakland Strategic Plan

The Port's current Strategic Plan is effective for fiscal years 2011-2015. The Plan outlines the goals and objectives of the next five years. Policies of interest are provided in this section.

Goals

- **Goal G: Sustain healthy communities through leading edge environmental stewardship**
  - Objective 1: Ensure effective communication and education regarding environmental and safety standards with business partners and the community.
  - Objective 2: Partner to share risk, accountability, benefits, and improve environmental and safety compliance.
  - Objective 5: Develop effective relationship with regulatory and resource agencies.
- **Goal E: Improve the processes for evaluating and managing capital expenditures and for long term management of Port property and infrastructure**
- **Goal K: Promote a proactive and responsive communications model**
  - Objective 1: Develop a strategic and comprehensive communications plan

which reaches out to a wide range of internal and external stakeholders and incorporates state-of-the-art practices and technology.

In addition to overarching goals and objectives, themed implementation phases are included:

- **Stage II (FY 11-12), "Market and Design": External focus on intelligence and marketing efforts to sharpen market niche, strengthen business and government relationships, complete negotiations, and then design solutions that deliver price, value and service to Port customers.**
- **Stage III (FY 12-13), "Build": Implement Stage II efforts**
- **Stage V (FY 14-15), "Sustain": Focus on sustained growth and optimal performance**

Source: Port of Oakland Strategic Plan, 2010, pp. 12-27.

The Port generally recognizes stakeholder involvement, although it remains uncertain as to whether environmental and safety concerns encompass Port-related operations external to Port property.

Comprehensive Truck Management Program (CTMP)

The Port maintains a Port Registry for drayage operators, with the intention of better operational safety and truck data management. The program is limited to knowledge of truck movements on Port property. The CTMP is based on the Port's desire to "…increase its maritime safety and security domain awareness, outreach capabilities, and general knowledge of the trucking entities and trucking operations conducted on

Seaport property.”; only registered trucks are authorized to “serve Seaport facilities” (Port of Oakland, 2010).

Port of Oakland Truck Tracker Program

In 2007, the Port of Oakland introduced the Truck Tracker Program, a GPS-based system designed to better manage drayage data. The impetus is similar to the CTMP whereby the Port intends greater oversight and security over shipping operations. The program creates potential leverage for future truck traffic policy emphasis through real-time data supply. As of program implementation, 200 truckers, in addition to two major shippers and ocean carriers were participating (Port of Oakland, 2007). However, enhanced access to truck-specific container movement data is apparently restricted to carrier and shipper tracking systems and staff (Port of Oakland, 2007).

Related to Pavement & Infrastructure Impacts

Oakland Army Base Redevelopment

The Oakland Army Base redevelopment is based on a multimodal policy direction. A significant portion of the redevelopment project involves rail yard expansion, to include more ship-to-rail transfers (Port of Oakland, 2011). The project envisions a “World class logistics center” designed specifically to reduce truck traffic and emissions related to Port activity (Port of Oakland, 2011). Pavement stress mitigation is indirectly addressed in this instance through actions to curtail growth in truck traffic. The Port recognizes therefore that drayage impacts are extensive enough to propose major new infrastructure construction aimed at balancing freight modal splits. However, the proposal does not indicate the extent to which splits would be balanced. Furthermore, as the MTC

Regional Goods Movement Study (2004) projects, freight volume growth could be substantial (p. 14), such that an improved truck-rail freight split is offset by increased truck VMTs and ton-miles traveled.

Figure 5-1. Oakland Army Base Redevelopment Area

Source: Port of Oakland Oakland Army Base Redevelopment RFQ, Appendix 1, 2009.

Strategic Alliance with Northwest Container Services, Inc.

In 2004, the Port of Oakland, along with Northwest Container Services, Inc. (NWCS) formed an association with the California Integrated Logistics Center (CILC), located in Shafter, CA, for "dedicated rail logistics serving international marine terminals at the Port of Oakland" (Port of Oakland, 2004). This is an attempt to create intermodal connections in which rail and truck modes can complement each other.

5.6. Recommendations & Conclusions

Drayage operations are critical to goods movement, especially as short-haul options, since trucks typically access urban areas more effectively than rail (Bryan, 2007. p. 6). However, trucks command significant freight modal split at the Port of Oakland and findings support growing truck traffic trends in the near and long term future. Subsequent pavement impacts appear inevitable proximate to the Port of Oakland.

Ultimately, singular policies are unlikely to resolve current negative impacts. Effective freight policymaking requires complementary policies that address multiple facets of logistics networks (Fischer, Hicks, and Cartwright, 2006; Holguin-Veras, 2008). Furthermore, appropriate policy selection depends on port program objectives (Fischer, Hicks, and Cartwright, 2006, p. 3). The Port of Oakland's Strategic Plan illuminates certain primary goals and objectives that broadly address local community impacts and seek optimization of Port operations.

Proposals put forth by the Port of Oakland address demand for future goods movement to some extent. The Oakland Army Base redevelopment, for example, is a major step towards accommodating increasing freight demand, especially considering the emphasis on expanding rail capacity near the Port. Infrastructural policies and improvements, however, appear limited to Port jurisdiction. Future, pavement impact mitigation may rely on interagency collaboration to develop equitable districts capable of forging policies and programs that address truck traffic effects on regional roadways.

5.6.1. Systemic Recommendations

- Develop data transparency regarding disaggregated truck movements at the Port by enhancing current Truck Tracker program
- Develop regional pavement survey per highway segments, to complement current, aggregated, countywide reports
- Review California Streets & Highways code Division 3, Chapter 4.9 Port-Related Cargo for comprehensive application to all state ports, to further aid goods movement policy decisions
- Initiate dialogue regarding pavement rehabilitation district specific to Port-related traffic impacts, including a proposed task force between the Port, the City, and MTC, dedicated to infrastructure oversight, budgeting, and maintenance
- Include pavement impacts in environmental and safety considerations for the Port of Oakland Strategic Plan

5.6.2. Study Recommendations

This study explores and estimates Port activity effects on freight trucking patterns and associated roadway impacts. The case study is specific to the Port of Oakland and selected study corridors that accommodate container drayage. Additional parameters are noted through which more robust contextual study may take place in the future.

Recommendations for future study are as follows:

- Access and review the Port's Truck Tracker program and similar GPS-container tracking data, for maximum commodity disaggregation
- Detailed origin-destination pairs may enable more precise corridor selection for study; currently the Commodity Flow Survey disaggregates regional truck traffic flows, but is not port-specific
- Disseminate Port-specific trucking on I-580, to attain comprehensive network impact insights
- Detail freight rail movements related to Port operations and container throughput

Appendices

Definitions

Definitions are provided to clarify terminology used throughout the study. Although alternative definitions may exist for specific terms, the definitions provided are particular to the context of this study.

Average Annual Daily Traffic (AADT): General vehicular traffic sampled by Caltrans at highway milepost locations over the course of a year

Average Annual Daily Truck Traffic (AADTT): Truck traffic sampled by Caltrans at highway milepost locations over the course of a year

Container: a corrugated steel box capable of securely storing goods for shipment

Corridor: a strategic highway segment serving high-speed vehicular traffic, particularly freight traffic

Caltrans: an abbreviated title for the California Department of Transportation

Drayage: freight trucking services

Elasticity: the responsiveness of one variable with respect to another, such that a 1% increase or decrease in the first variable corresponds to a 1% increase or decrease in the opposite variable.

Export: shipped goods exiting an origin market (i.e., region, nation)

Freight: raw and refined goods transported in bulk units by a variety of transport modes, including maritime, drayage, rail, and air.

Hinterland: of, or pertaining to, freight transport via land-based mode(s); also overland or landside shipment

Import: shipped goods entering a destination market (i.e., region, nation)

Logistics: study of goods movement efficiency, based on various subsets of the freight transport industry, including shipping, receiving, warehousing, and tracking sectors

Linear regression: a statistical technique to decipher variable relationships, called correlations; gamma (r) values indicate correlational strength through coefficients of determination (r^2)

Maritime: of, or relating to, the oceans and seas; also, a seafaring mode of transport

Performance Management System (PeMS): a Caltrans real-time data repository that also features statewide, archived data for roadway vehicle movements

Port of Oakland: a nearly 1,000-acre seaport serving primarily container freight movement via maritime and landside transport facilities within the San Francisco Bay Area; the Port is the 5th largest container seaport in the U.S. by volume.

Traffic Index (TI): A pavement stress scale, defined in the Caltrans Highway Design Manual; values range from 5.0 to 17.5 and indicate the extent to which paved state highways are capable of reaching intended serviceability throughout the design life of the roadway

TEU-Qualified Trucks: Trucks identified as likely container-hauling transport, based on axle and trailer characteristics, including minimum three axles and single-trailer (ST) placement

Twenty-foot equivalent unit (TEU): an internationally recognized standard unit of measurement for shipping containers: 20 feet long by 8 feet wide and approximately 8 feet tall.

Vessel: a maritime vehicle, also known as a ship or boat

Appendix to Chapter 2. Background

Sector 00: CF0700P2: 2007 Commodity Flow Survey: CFS Advance Report: Shipment Characteristics by Total Modal Activity: 2007

Geographic Area Name	Meaning of Mode category	Ton-miles (mil)	% Share	Avg miles	Ton-miles CV	Avg miles CV
United States	All modes	3,490,806	100.00%	577	3.7	1.9
United States	Truck	1,400,654	40.12%	186	1.8	3.3
United States	Rail	1,496,353	42.87%	842	6.5	2.9
United States	Shallow draft	283,519	8.12%	222	7	9.4
United States	Great Lakes	41,066	1.18%	429	29.6	9.8
United States	Deep draft	100,534	2.88%	1,597	14.1	5.3
United States	Air (incl truck and air)	4,166	0.12%	1,154	15.4	2.2
United States	Pipeline	S	S	S	S	S
United States	Parcel, U.S.P.S. or courier	29,426	0.84%	911	3.1	1.5
United States	Other and unknown modes	41,271	1.18%	103	7.9	11
		TOTAL	97%			

Inbound Shipment Characteristics by Mode of Transportation for Metropolitan Area of Destination
1997 Commodity Flow Survey (US Economic Census)
San Jose-San Francisco-Oakland, CA Combined Statistical Area

Mode Category	Year	Value($mil)	Tons(thous)	Ton-miles(mil)	Avg miles	Value CV	Tons CV	Ton miles CV	Avg miles CV
All modes	1997	200,022	175,421	35,518	819	N/A	N/A	N/A	N/A
Single modes	1997	150,298	163,361	31,029	260	N/A	N/A	N/A	N/A
Truck	1997	132,156	132,737	20,630	180	N/A	N/A	N/A	N/A
Rail	1997	5,104	7,634	9,449	2,036	N/A	N/A	N/A	N/A
All other single modes	1997	13,038	22,990	950	1,944	N/A	N/A	N/A	N/A
Muliple modes	1997	38,924	1,943	3,038	1,447	N/A	N/A	N/A	N/A
Parcel, USPS, or courier	1997	36,011	595	626	1,445	N/A	N/A	N/A	N/A
Other multiple modes	1997	2,913	1,348	2,412	2385	N/A	N/A	N/A	N/A
Other and unknown modes	1997	10,800	10,116	1,451	111	N/A	N/A	N/A	N/A
Other		23,838	33,107						

Shipment Characteristics by Mode of Transportation for Metropolitan Area of Origin
1997 Commodity Flow Survey (US Economic Census)
San Jose-San Francisco-Oakland, CA Combined Statistical Area

Mode Category	Year	Value($mil)	Tons(thous)	Ton-miles(mil)	Avg miles	Value CV	Tons CV	Ton miles CV	Avg miles CV
All modes	1997	212,831	172,612	23,664	710	N/A	N/A	N/A	N/A
Single modes	1997	151,650	158,717	18,301	319	N/A	N/A	N/A	N/A
Truck	1997	121,840	120,938	13,120	226	N/A	N/A	N/A	N/A
Rail	1997	1,134	5,100	2,685	1,197	N/A	N/A	N/A	N/A
All other single modes	1997	28,676	32,679	2,496	2,016	N/A	N/A	N/A	N/A
Muliple modes	1997	46,629	1,381	2,449	1,215	N/A	N/A	N/A	N/A
Parcel, USPS, or courier	1997	45,572	672	664	1,214	N/A	N/A	N/A	N/A
Other multiple modes	1997	1,057	709	1,785	2,097	N/A	N/A	N/A	N/A
Other and unknown modes	1997	14,551	12,514	2,914	163	N/A	N/A	N/A	N/A
Other		43,228	45,193						

Sector: CF0700A26: Geographic Area Series: Shipment Characteristics by Destination Metro Areas
2002 Commodity Flow Survey (US Economic Census)
San Jose-San Francisco-Oakland, CA Combined Statistical Area

Mode Category	Year	Value($mil)	Tons(thous)	Ton-miles(mil)	Avg miles	Value CV	Tons CV	Ton miles CV	Avg miles CV
All modes	2002	207,916	174,664	53,165	861	8.1	9.5	17.5	13.0
Single modes	2002	166,868	166,067	48,594	398	9.3	9.7	16.6	17.0
Truck	2002	137,309	126,268	36,501	251	10.6	11.7	2`.4	14.8
Rail	2002	4,320	7,339	10,796	1,520	18.9	15.1	19.4	12.0
All other single modes	2002	25,239	32,460	1,297	2,343	19.1	21.1	28.4	5.5
Muliple modes	2002	35,509	1,226	2,132	1,212	9.2	9.4	10.4	12.4
Parcel, USPS, or courier	2002	33,940	568	774	1,212	9.2	6.8	7.9	12.4
Other multiple modes	2002	1,569	658	1,358	2,448	20.6	16.2	16.4	3.7
Other and unknown modes	2002	5,539	S	S	S	20.6	S	S	S
Other		30,778	39,831						

Sector: CF0700A26: Geographic Area Series: Shipment Characteristics by Destination Metro Areas
2007 Commodity Flow Survey (US Economic Census)
San Jose-San Francisco-Oakland, CA Combined Statistical Area

Mode Category	Year	Value($mil)	Tons(thous)	Ton-miles(mil)	Avg miles	Value CV	Tons CV	Ton miles CV	Avg miles CV
All modes	2007	281,133	224,816	45,658	948	6.2	18.4	13.1	4.6
Single modes	2007	211,915	201,277	37,264	321	7.4	20.2	13.9	20.8
Truck	2007	168,257	171,835	23,170	277	7.6	23.0	10.8	24.6
For-hire truck	2007	85,170	48,276	16,126	839	5.1	11.2	4.9	10.6
Private truck	2007	83,087	123,559	7,043	49	12.8	32.0	36.9	7.5
Rail	2007	8,594	10,197	10,611	1,410	26.2	25.7	23.3	11.7
Air (incl. truck & air)	2007	23,965	101	170	1,431	21.1	19.4	28.9	5.4
Muliple modes	2007	64,087	S	7,890	1,463	11.2	S	28.0	3.0
Truck and rail	2007	4,010	4,008	4,200	2,600	32.2	42.5	39.2	5.7
Truck and water	2007	S	S	S	S	S	S	S	S
Rail and water	2007	S	S	52	S	S	S	41.5	S
Other multiple modes	2007	S	S	44	S	S	S	44.2	S
Other and unknown modes	2007	5,131	6,406	504	S	14.8	46.9	26.0	S
Other		16,230	42,683						

MASTER US CENSUS METRO DESTINATION TABLE

Mode Category	Value($mil) 1997	2002	%	2007	%	Tons(thous) 1997	2002	%	2007	%	Ton-miles(mil) 1997	2002	%	2007	%	Avg miles 1997	2002	%	2007	%
All modes	200,022	207,916	3.9%	281,133	35.2%	175,421	174,664	-0.4%	224,816	28.7%	35,518	23,664	-33.4%	45,658	92.9%	819	861	5.1%	948	10.1%
Single modes	150,298	166,868	11.0%	211,915	27.0%	163,361	166,067	1.7%	201,277	21.2%	31,029	18,301	-41.0%	37,264	103.6%	260	398	53.1%	321	-19.3%
Truck	132,156	137,309	3.9%	168,257	22.5%	132,737	126,268	-4.9%	171,835	36.1%	20,630	13,120	-36.4%	23,170	76.6%	180	251	39.4%	277	10.4%
For-hire truck				85,170					48,276					16,126					839	
Private truck				83,087					123,559					7,043					49	
Rail	5,104	4,320	-15.4%	8,594	98.9%	7,634	7,339	-3.9%	10,197	38.9%	9,449	2,685	-71.6%	10,611	295.2%	2,036	1,520	-25.3%	1,410	-7.2%
Air (incl. truck & air)	-	-	-	23,965	-	-	-	-	101	-	-	-	-	170	-	-	-	-	1,431	-
Muliple modes	38,924	35,509	-8.8%	64,087	80.5%	1,943	1,226	-36.9%	S	-	3,038	2,449	-19.4%	7,890	222.2%	1,447	1,212	-16.2%	1,463	20.7%
Truck and rail				4,010					4,008					4,200					2,600	
Truck and water				S					S					S					S	
Parcel, USPS, or courier	36,011	33,940	-5.8%			595	568	-4.5%			626	664	6.1%			1,445	1,212	-16.1%		
Rail and water				S					S					52					S	
All other single modes	13,038	25,239	93.6%			22,990	32,460	41.2%			950	2,496	162.7%			1,944	2,343	20.5%	-	
Other multiple modes	2,913	1,569	-46.1%	S		1,348	658	-51.2%	S		2,412	1,785	-26.0%			2385	2,448	2.6%	S	
Other and unknown modes	10,800	5,539	-48.7%	5,131	-7.4%	10,116	S		6,406		1,451	2,914	100.8%	504	-82.7%	111	S		S	
Other	23,838	30,778	29.1%	16,230	-47.3%	33,107	39,831	20.3%	42,683	7.2%										

Port of Oakland Top 15 Commodities by Value (2009)

IMPORTS (Containerized)

Commodity	$ US	% Share
Machinery	4,505,059,595	22.4%
Electric Machinery	2,311,931,501	11.5%
Furniture & Bedding	1,157,945,773	5.8%
Beverages	1,098,462,862	5.5%
Knit Apparel	965,170,995	4.8%
Woven Apparel	973,650,252	4.8%
Vehicles, Not Railway	791,443,226	3.9%
Toys & Sports Equipment	670,669,726	3.3%
Plastics	595,123,642	3.0%
Medical Instruments	501,629,052	2.5%
Spices, Coffee & Tea	425,327,598	2.1%
Ores, Slag, Ash	410,554,983	2.0%
Iron/Steel Products	383,759,415	1.9%
Wood	362,203,666	1.8%
Misc. Textile Articles	337,771,124	1.7%
SUBTOTAL	**15,490,703,410**	**77.1%**
OTHER COMMODITIES	**4,602,879,290**	**22.9%**
TOTAL	**20,093,582,700**	**100.0%**

EXPORTS (Containerized)

Commodity	$ US	% Share
Edible Fruit & Nuts	1,802,488,645	17.5%
Meat	1,387,402,038	13.4%
Machinery	652,968,766	6.3%
Beverages	546,447,853	5.3%
Inorg Chem; Rare Earth Mt.	521,713,711	5.1%
Vehicles, Not Railway	472,425,475	4.6%
Cereals	420,587,190	4.1%
Electric Machinery	408,922,836	4.0%
Medical Instruments	363,486,419	3.5%
Misc. Chemical Products	275,086,168	2.7%
Organic Chemicals	259,947,329	2.5%
Plastic	231,468,276	2.2%
Aluminum	202,256,021	2.0%
Hides & Skins	201,052,502	**1.9%**
Iron & Steel	185,612,282	1.8%
SUBTOTAL	**7,931,865,511**	**76.9%**
OTHER COMMODITIES	**2,388,007,149**	**23.1%**
TOTAL	**10,319,872,660**	**100.0%**

Port of Oakland Container (TEUs) Throughput (1990-2010)

Year	Full Import	Full Export	Empty Import	Empty Export	Total	Trend (% Change)
1990	253,864	600,595	218,366	51,298	1,124,123	3.1%
1991	286,696	630,557	228,789	48,676	1,194,718	6.3%
1992	354,490	656,674	205,737	74,593	1,291,494	8.1%
1993	365,114	667,879	202,866	69,275	1,305,134	1.1%
1994	403,845	764,237	249,600	73,300	1,490,982	14.2%
1995	404,842	809,894	266,506	68,644	1,549,886	4.0%
1996	360,717	782,913	283,314	71,258	1,498,202	-3.3%
1997	398,157	769,172	288,304	75,555	1,531,188	2.2%
1998	458,470	747,064	237,176	132,696	1,575,406	2.9%
1999	469,226	798,873	234,121	170,536	1,672,756	6.2%
2000	503,858	818,521	244,359	210,184	1,776,922	6.2%
2001	486,389	758,958	223,894	174,344	1,643,585	-7.5%
2002	547,230	732,537	206,418	221,642	1,707,827	3.9%
2003	599,411	799,547	206,267	317,879	1,923,104	12.6%
2004	694,314	813,716	184,863	354,611	2,047,504	6.5%
2005	836,258	846,579	197,988	393,165	2,273,990	11.1%
2006	877,778	840,145	192,455	481,367	2,391,745	5.2%
2007	870,284	909,633	204,943	403,051	2,387,911	-0.2%
2008	796,404	910,700	192,569	333,860	2,233,533	-6.5%
2009	701,501	966,882	209,258	167,570	2,045,211	-8.4%
2010	802,913	954,814	201,179	362,308	2,321,214	13.5%

Port of Oakland Container (TEUs) Throughput Decade Trends							
	Full		Empty				
Year	Import	Export	Import	Export	Total	Trend (% Change)	Trend (Tot. Change)
1990	253,864	600,595	218,366	51,298	1,124,123		
2000	503,858	818,521	244,359	210,184	1,776,922		
2009	701,501	966,882	209,258	167,570	2,045,211		
% Change 1990-2009	176%	61%	-4%	227%	82%	**81.9%**	921,088
% Change 2000-2009	39%	18%	-14%	-20%	15%	**15.1%**	268,289

Total Imports 1990-2009	92.86%
%share of Trend	47.61%
Total Exports 1990-2009	74.02%
%share of Trend	52.39%

Total Imports 2000-2009	21.72%
%share of Trend	60.58%
Total Exports 2000-2009	10.28%
%share of Trend	39.42%

Appendix to Chapter 4. Results & Analysis

4.2. Descriptive Results

4.2.1. Container Throughput

Port of Oakland Historical Container Throughput, 1990-2010

Year	Full	Empty	Total Combined
1990	854,459	269,664	1,124,123
1991	917,253	277,465	1,194,718
1992	1,011,164	280,330	1,291,494
1993	1,032,993	272,141	1,305,134
1994	1,168,082	322,900	1,490,982
1995	1,214,736	335,150	1,549,886
1996	1,143,630	354,572	1,498,202
1997	1,167,329	363,859	1,531,188
1998	1,205,534	369,872	1,575,406
1999	1,268,099	404,657	1,672,756
2000	***1,322,379***	***454,543***	***1,776,922***
2001	***1,245,347***	***398,238***	***1,643,585***
2002	***1,279,767***	***428,060***	***1,707,827***
2003	***1,398,958***	***524,146***	***1,923,104***
2004	***1,508,030***	***539,474***	***2,047,504***
2005	***1,682,837***	***591,153***	***2,273,990***
2006	***1,717,923***	***673,822***	***2,391,745***
2007	***1,779,917***	***607,994***	***2,387,911***
2008	***1,707,104***	***526,429***	***2,233,533***
2009	***1,668,383***	***376,828***	***2,045,211***
2010	1,757,727	563,487	2,321,214
difference	***346,004***	***(77,715)***	***268,289***
% change	***26.17%***	***-17.10%***	***15.10%***
elasticity	***-1.5304***	***[2000-2009]***	

Port of Oakland Full & Empty TEU Throughput, 1990-2010

Year	Total Full	Total Empty	Total Combined
1990	854,459	269,664	1,124,123
1991	917,253	277,465	1,194,718
1992	1,011,164	280,330	1,291,494
1993	1,032,993	272,141	1,305,134
1994	1,168,082	322,900	1,490,982
1995	1,214,736	335,150	1,549,886
1996	1,143,630	354,572	1,498,202
1997	1,167,329	363,859	1,531,188
1998	1,205,534	369,872	1,575,406
1999	1,268,099	404,657	1,672,756
2000	1,322,379	454,543	1,776,922
2001	1,245,347	398,238	1,643,585
2002	1,279,767	428,060	1,707,827
2003	1,398,958	524,146	1,923,104
2004	1,508,030	539,474	2,047,504
2005	1,682,837	591,153	2,273,990
2006	1,717,923	673,822	2,391,745
2007	1,779,917	607,994	2,387,911
2008	1,707,104	526,429	2,233,533
2009	1,668,383	376,828	2,045,211
2010	1,757,727	563,487	2,321,214
difference	***346,004***	***(77,715)***	***268,289***
% change	***26.17%***	***-17.10%***	***15.10%***
elasticity	***-1.5304***	***[2000-2009]***	

Port of Oakland Import & Export Throughput, 1990-2010

Year	Total Imports	Total Exports	Total Combined
1990	472,230	651,893	1,124,123
1991	515,485	679,233	1,194,718
1992	560,227	731,267	1,291,494
1993	567,980	737,154	1,305,134
1994	653,445	837,537	1,490,982
1995	671,348	878,538	1,549,886
1996	644,031	854,171	1,498,202
1997	686,461	844,727	1,531,188
1998	695,646	879,760	1,575,406
1999	703,347	969,409	1,672,756
2000	748,217	1,028,705	1,776,922
2001	710,283	933,302	1,643,585
2002	753,648	954,179	1,707,827
2003	805,678	1,117,426	1,923,104
2004	879,177	1,168,327	2,047,504
2005	1,034,246	1,239,744	2,273,990
2006	1,070,233	1,321,512	2,391,745
2007	1,075,227	1,312,684	2,387,911
2008	988,973	1,244,560	2,233,533
2009	910,759	1,134,452	2,045,211
2010	1,004,092	1,317,122	2,321,214
difference	***162,542***	***105,747***	***268,289***
% change	***21.72%***	***10.28%***	***15.10%***
elasticity	***2.1133***	***[2000-2009]***	

Port of Oakland Full & Empty TEU Throughput, 1990-2010

Year	Total Full	Total Empty	Total Combined
1990	854,459	269,664	1,124,123
1991	917,253	277,465	1,194,718
1992	1,011,164	280,330	1,291,494
1993	1,032,993	272,141	1,305,134
1994	1,168,082	322,900	1,490,982
1995	1,214,736	335,150	1,549,886
1996	1,143,630	354,572	1,498,202
1997	1,167,329	363,859	1,531,188
1998	1,205,534	369,872	1,575,406
1999	1,268,099	404,657	1,672,756
2000	1,322,379	454,543	1,776,922
2001	1,245,347	398,238	1,643,585
2002	1,279,767	428,060	1,707,827
2003	1,398,958	524,146	1,923,104
2004	1,508,030	539,474	2,047,504
2005	1,682,837	591,153	2,273,990
2006	1,717,923	673,822	2,391,745
2007	1,779,917	607,994	2,387,911
2008	1,707,104	526,429	2,233,533
2009	1,668,383	376,828	2,045,211
2010	1,757,727	563,487	2,321,214
difference	***346,004***	***(77,715)***	***268,289***
% change	***26.17%***	***-17.10%***	***15.10%***
elasticity	***-1.5304***	***[2000-2009]***	

Port of Oakland Import & Export Throughput, 1990-2010

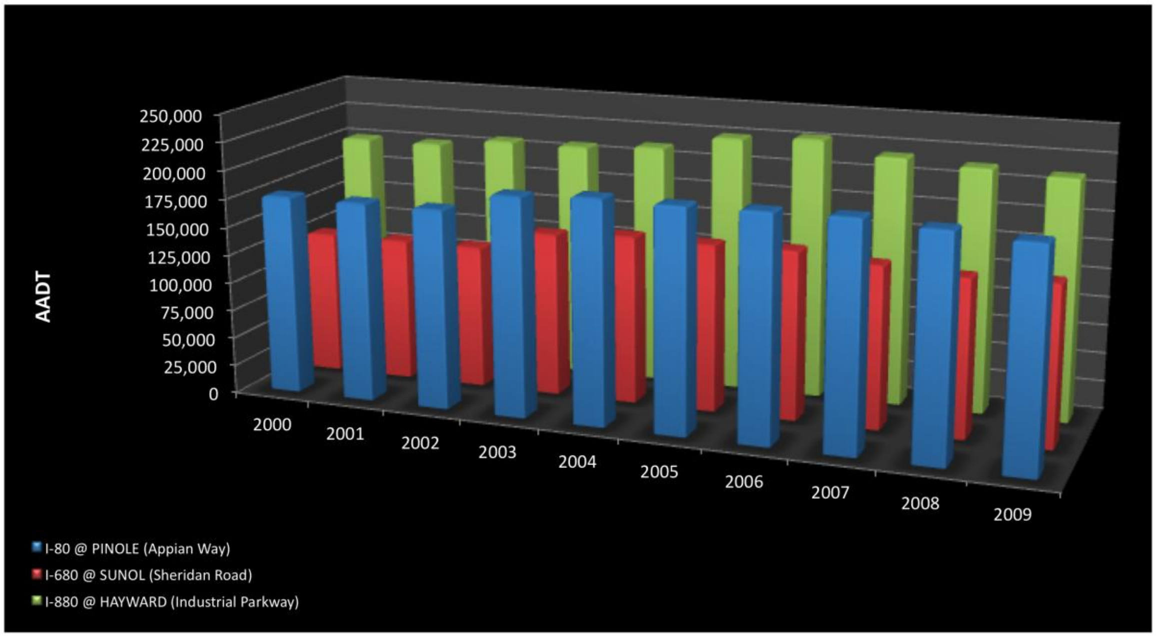
Year	Total Imports	Total Exports	Total Combined
1990	472,230	651,893	1,124,123
1991	515,485	679,233	1,194,718
1992	560,227	731,267	1,291,494
1993	567,980	737,154	1,305,134
1994	653,445	837,537	1,490,982
1995	671,348	878,538	1,549,886
1996	644,031	854,171	1,498,202
1997	686,461	844,727	1,531,188
1998	695,646	879,760	1,575,406
1999	703,347	969,409	1,672,756
2000	748,217	1,028,705	1,776,922
2001	710,283	933,302	1,643,585
2002	753,648	954,179	1,707,827
2003	805,678	1,117,426	1,923,104
2004	879,177	1,168,327	2,047,504
2005	1,034,246	1,239,744	2,273,990
2006	1,070,233	1,321,512	2,391,745
2007	1,075,227	1,312,684	2,387,911
2008	988,973	1,244,560	2,233,533
2009	910,759	1,134,452	2,045,211
2010	1,004,092	1,317,122	2,321,214
difference	***162,542***	***105,747***	***268,289***
% change	***21.72%***	***10.28%***	***15.10%***
elasticity	***2.1133***	***[2000-2009]***	

Port of Oakland Total Combined TEU Throughput, 2000-2009

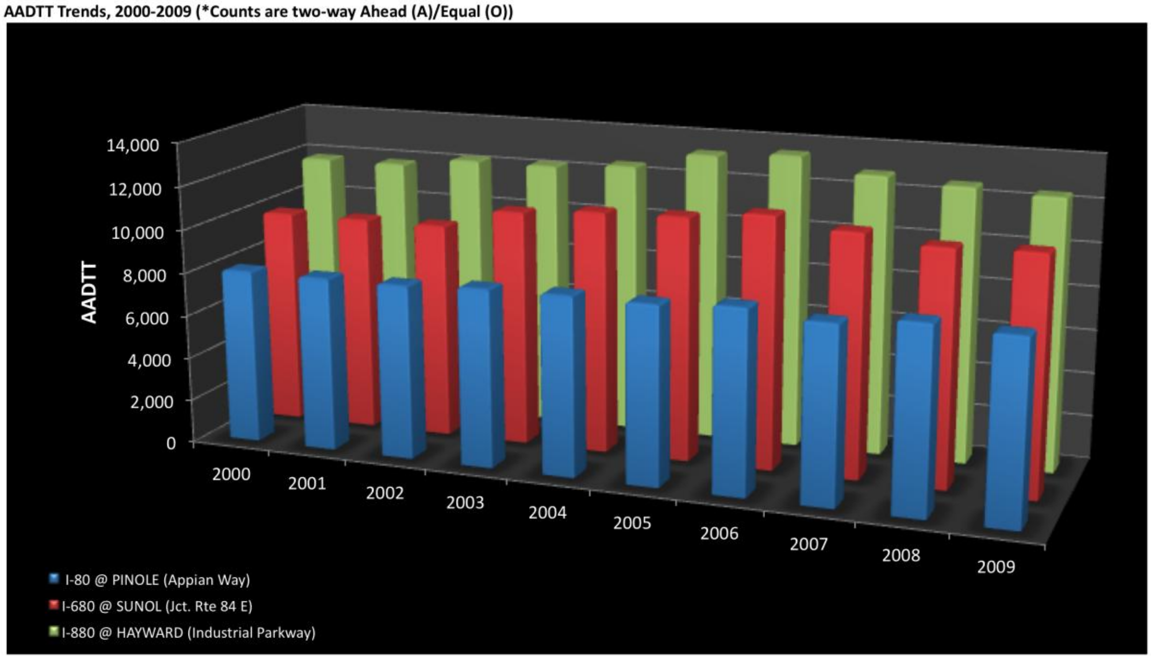
	X	Y
	Full	Empty
2000	1,322,379	454,543
2001	1,245,347	398,238
2002	1,279,767	428,060
2003	1,398,958	524,146
2004	1,508,030	539,474
2005	1,682,837	591,153
2006	1,717,923	673,822
2007	1,779,917	607,994
2008	1,707,104	526,429
2009	1,668,383	376,828
difference	***346,004***	***(77,715)***
% change	***26.17%***	***-17.10%***
elasticity	***-1.5304***	[2000-2009]

4.2.2. AADTT v. AADTs

AADT Trends, 2000-2009 (*Counts are two-way Ahead (A))



AADTT Trends, 2000-2009 (*Counts are two-way Ahead (A)/Equal (O))



I-80 @ PINOLE (Appian Way) **AADT**

Year	Back Peak Hour	Back Peak Month	Back AADT	Ahead Peak Hour	Ahead Peak Month	Ahead AADT
2000	11900	193000	184000	11800	184000	176000
2001	11900	193000	184000	11800	184000	176000
2002	11900	193000	184000	11800	184000	176000
2003	12400	199000	188000	12800	203000	193000
2004	12500	200000	189000	13000	207000	197000
2005	12400	199000	188000	13000	206000	196000
2006	13000	197000	193000	13200	201000	197000
2007	**13000**	**198000**	**194000**	**13300**	**202000**	**198000**
2008	12700	194000	190000	13000	198000	194000
2009	12,600	192,000	186,000	12,900	196,000	190,000

I-80 @ PINOLE (Appian Way) **AADTT**

Year	Route	Route Suffix	District	County	Postmile Prefix	Postmile	Leg	AADT Total	Total Trucks	Total Truck %	2 Axle Volume	2 Axle Percent	3 Axle Volume	3 Axle Percent	4 Axle Volume	4 Axle Percent	5 Axle Volume	5 Axle Percent	Description	Year	Verify/ Estimate
2000	80		4	CC		7.597	O	184000	8036	4.37	2463	30.65	608	7.57	237	2.95	4728	58.84	PINOLE, APPIA	00	V
2001	80		4	CC		7.597	O	184000	8036	4.37	2463	30.65	608	7.57	237	2.95	4728	58.84	PINOLE, APPIA	00	V
2002	80		4	CC		7.597	O	184000	8041	4.37	2465	30.65	609	7.57	237	2.95	4731	58.84	PINOLE, APPIA	0	V
2003	80		4	CC		7.597	B	188000	7859	4.18	2506	31.89	511	6.5	276	3.51	4566	58.1	PINOLE, APPIA	03	V
2003	80		4	CC		7.597	O	188000	8216	4.37	2518	30.65	622	7.57	242	2.95	4834	58.84	PINOLE, APPIA	00	V
2004	80		4	CC		7.597	B	189000	7900	4.18	2519	31.89	514	6.5	277	3.51	4590	58.1	PINOLE, APPIA	3	V
2004	80		4	CC		7.597	O	189000	8259	4.37	2531	30.65	625	7.57	244	2.95	4860	58.84	PINOLE, APPIA	0	V
2005	80		4	CC		7.597	B	188000	7858	4.18	2506	31.89	511	6.5	276	3.51	4565	58.1	PINOLE, APPIA	03	V
2005	80		4	CC		7.597	O	188000	8216	4.37	2518	30.65	622	7.57	242	2.95	4834	58.84	PINOLE, APPIA	00	V
2006	80		4	CC		7.597	B	193000	8067	4.18	2573	31.89	524	6.5	283	3.51	4687	58.1	PINOLE, APPIA	3	V
2006	80		4	CC		7.597	O	193000	8434	4.37	2585	30.65	638	7.57	249	2.95	4963	58.84	PINOLE, APPIA	0	V
2007	80		4	CC		7.597	B	194000	8109	4.18	2586	31.89	527	6.5	285	3.51	4711	58.1	PINOLE, APPIAN WAY	03	V
2008	80		4	CC		7.597	B	190000	7942	4.18	2533	31.89	516	6.5	279	3.51	4614	58.1	PINOLE, APPIAN WAY	03	V
2008	80		4	CC		7.597	O	194000	8478	4.37	2599	30.65	642	7.57	250	2.95	4988	58.84	PINOLE, APPIAN WAY	00	V
2009	80		4	CC		7.597	B	186000	7775	4.18	2479	31.89	505	6.5	273	3.51	4517	58.1	PINOLE, APPIAN WAY	03	V
2009	80		4	CC		7.597	O	190000	8303	4.37	2545	30.65	629	7.57	245	2.95	4885	58.84	PINOLE, APPIAN WAY	00	V

: incorporates Ahead Leg counts

I-680 @ SUNOL (Sheridan Road) **AADT**

Year	Back Peak Hour	Back Peak Month	Back AADT	Ahead Peak Hour	Ahead Peak Month	Ahead AADT
2000	8300	141000	129000	8300	137000	126000
2001	8300	141000	129000	8300	137000	126000
2002	8300	141000	129000	8300	137000	126000
2003	10600	159000	145000	10600	158000	144000
2004	10900	163000	149000	10900	163000	148000
2005	10800	162000	148000	10900	161000	147000
2006	11300	154000	149000	11200	153000	148000
2007	**10800**	**150000**	**142000**	**10800**	**150000**	**142000**
2008	10500	146000	138000	10500	146000	138000
2009	10,800	146,000	142,000	10,700	144,000	140,000

I-680 @ SUNOL (Jct. Rte 84 E) **AADTT**

Year	Route	Route Suffix	District	County	Postmile Prefix	Postmile	Leg	AADT Total	Total Trucks	Total Truck %	2 Axle Volume	2 Axle Percent	3 Axle Volume	3 Axle Percent	4 Axle Volume	4 Axle Percent	5 Axle Volume	5 Axle Percent	Description	Year	Verify/ Estimate
2000	680		4	ALA	R	11.845	A	108000	9936	9.2	2862	28.8	964	9.7	845	8.5	5266	53	JCT. RTE. 84 EA	94	V
2001	680		4	ALA	R	11.845	A	108000	9936	9.2	2862	28.8	964	9.7	845	8.5	5266	53	JCT. RTE. 84 EA	94	V
2002	680		4	ALA	R	11.845	A	108000	9936	9.2	2862	28.8	964	9.7	845	8.5	5266	53	JCT. RTE. 84 EA	94	V
2003	680		4	ALA	R	11.845	A	118000	10856	9.2	3127	28.8	1053	9.7	923	8.5	5754	53	JCT. RTE. 84 EA	94	V
2004	680		4	ALA	R	11.845	A	121000	11132	9.2	3206	28.8	1080	9.7	946	8.5	5900	53	JCT. RTE. 84 EA	94	V
2005	680		4	ALA	R	11.845	A	122000	11224	9.2	3233	28.8	1089	9.7	954	8.5	5949	53	JCT. RTE. 84 EA	94	V
2006	680		4	ALA	R	11.845	A	126000	11592	9.2	3338	28.8	1124	9.7	985	8.5	6144	53	JCT. RTE. 84 EA	94	V
2007	680		4	ALA	R	11.845	A	121000	11132	9.2	3206	28.8	1080	9.7	946	8.5	5900	53	JCT. RTE. 84 EAST	94	V
2008	680		4	ALA	R	11.845	A	118000	10764	9.2	3100	28.8	1044	9.7	915	8.5	5705	53	JCT. RTE. 84 EAST	94	V
2009	680		4	ALA	R	11.845	A	118000	10856	9.2	3127	28.8	1053	9.7	923	8.5	5754	53	JCT. RTE. 84 EAST	94	V

I-880 @ HAYWARD (Industrial Parkway) **AADT**						
Year	Back Peak Hour	Back Peak Month	Back AADT	Ahead Peak Hour	Ahead Peak Month	Ahead AADT
2000	13700	201000	196000	14100	206000	201000
2001	13700	201000	196000	14100	206000	201000
2002	13800	201000	197000	14600	212000	208000
2003	13800	201000	197000	14600	212000	208000
2004	14100	206000	202000	14800	216000	212000
2005	13800	219000	212000	14600	232000	225000
2006	14000	223000	216000	14900	236000	229000
2007	**13300**	**212000**	**205000**	**14200**	**225000**	**218000**
2008	13800	203000	201000	14500	219000	214000
2009	13,600	200,000	198,000	14,300	216,000	211,000

I-880 @ HAYWARD (Industrial Parkway) **AADTT**																						
Year	Route	Route Suffix	District	County	Postmile Prefix	Postmile	Leg	AADT Total	Total Trucks	Total Truck %	2 Axle Volume	2 Axle Percent	3 Axle Volume	3 Axle Percent	4 Axle Volume	4 Axle Percent	5 Axle Volume	5 Axle Percent	Description	Year	Verify/ Estimate
2000	880		4	ALA		14.537	A	201000	11859	5.9	4744	40	1494	12.6	723	6.1	4898	41.3	HAYWARD, INC	96	V
2001	880		4	ALA		14.537	A	201000	11859	5.9	4744	40	1494	12.6	723	6.1	4898	41.3	HAYWARD, INC	96	V
2002	880		4	ALA		14.537	A	208000	12272	5.9	4909	40	1546	12.6	749	6.1	5068	41.3	HAYWARD, INC	96	V
2003	880		4	ALA		14.537	A	208000	12272	5.9	4909	40	1546	12.6	749	6.1	5068	41.3	HAYWARD, INC	96	V
2004	880		4	ALA		14.537	A	212000	12508	5.9	5003	40	1576	12.6	763	6.1	5166	41.3	HAYWARD, INC	96	V
2005	880		4	ALA		14.537	A	225000	13275	5.9	5310	40	1673	12.6	810	6.1	5483	41.3	HAYWARD, INC	96	V
2006	880		4	ALA		14.537	A	229000	13511	5.9	5404	40	1702	12.6	824	6.1	5580	41.3	HAYWARD, INC	96	V
2007	880		4	ALA		14.537	A	218000	12862	5.9	5145	40	1621	12.6	785	6.1	5312	41.3	HAYWARD, INDUSTRIAL PARKW	96	V
2008	880		4	ALA		14.537	A	214000	12626	5.9	5050	40	1591	12.6	770	6.1	5215	41.3	HAYWARD, INDUSTRIAL PARKW	96	V
2009	880		4	ALA		14.537	A	211000	12449	5.9	4980	40	1569	12.6	759	6.1	5141	41.3	HAYWARD, INDUSTRIAL PARKW	96	V

AADTT Share of AADT, 2000-2009

	I-80	I-680	I-880
2000	4.3700	9.2	5.9
2001	4.3700	9.2	5.9
2002	4.3700	9.2	5.9
2003	4.3700	9.2	5.9
2004	4.3700	9.2	5.9
2005	4.3700	9.2	5.9
2006	4.3700	9.2	5.9
2007	4.1800	9.2	5.9
2008	4.3700	9.2	5.9
2009	4.3700	9.2	5.9
Difference	*0.0000*	*0.0000*	*0.0000*
% Change	*0.00%*	*0.00%*	*0.00%*
Average	*4.3510*	*9.2000*	*5.9000*
Overall Avg.		*6.4837*	

4.2.3. AADTT v. TEUs

	X	Y
	Exports	AADTT
2000	1,028,705	11,859
2001	933,302	11,859
2002	954,179	12,272
2003	1,117,426	12,272
2004	1,168,327	12,508
2005	1,239,744	13,275
2006	1,321,512	13,511
2007	1,312,684	12,862
2008	1,244,560	12,626
2009	1,134,452	12,449
difference	*105,747*	*590*
% change	*10.28%*	*4.98%*
elasticity	*2.0662*	

	X	Y
	Imports	AADTT
2000	748,217	11,859
2001	710,283	11,859
2002	753,648	12,272
2003	805,678	12,272
2004	879,177	12,508
2005	1,034,246	13,275
2006	1,070,233	13,511
2007	1,075,227	12,862
2008	988,973	12,626
2009	910,759	12,449
difference	*162,542*	*590*
% change	*21.72%*	*4.98%*
elasticity	*4.3665*	

4.2.4 TEU-Qualified Trucks v. TEUs

I-80 Appian Way TEU-Qualified Trucks

Vehicle Class	# Vehicles	% Total			
Motorcycles	1030	0			
Cars	18729776	80.1			
2 Axle, 4T SU	3207833	13.7			
Bus	50966	0.2			
2 Axle,6T SU	486852	2.1			
3 Axle SU	108154	0.5			
4+ Axle SU	330	0			
< 4 Axle ST	108417	0.5			
5 Axle ST	560570	2.4			
6+ Axle ST	8216	0			
< 5 Axle MT	42878	0.2			
6 Axle MT	10043	0			
7+ Axle MT	620	0	SUM	730744	0.031239294
User-Def	13199	0.1			
Unknown	62938	0.3	SUM	23391822	1

Census Station 49020 - I-80 - Summary Table - Vehicle Classification - Jan 1-Dec 31 00

Vehicle Class	# Vehicles	% Total			
Motorcycles	761	0			
Cars	17477423	79.8			
2 Axle, 4T SU	3088931	14.1			
Bus	47558	0.2			
2 Axle,6T SU	480087	2.2			
3 Axle SU	102768	0.5			
4+ Axle SU	692	0			
< 4 Axle ST	98107	0.4			
5 Axle ST	490254	2.2			
6+ Axle ST	7662	0			
< 5 Axle MT	36058	0.2			
6 Axle MT	9809	0			
7+ Axle MT	618	0	SUM	642508	0.029322073
User-Def	11677	0.1			
Unknown	59688	0.3	SUM	21912093	1

Census Station 49020 - I-80 - Summary Table - Vehicle Classification - Jan 1-Dec 31 01

Vehicle Class	# Vehicles	% Total			
Motorcycles	509	0			
Cars	13646885	79.2			
2 Axle, 4T SU	2543867	14.8			
Bus	35765	0.2			
2 Axle,6T SU	394205	2.3			
3 Axle SU	74779	0.4			
4+ Axle SU	2040	0			
< 4 Axle ST	69807	0.4			
5 Axle ST	361325	2.1			
6+ Axle ST	5885	0			
< 5 Axle MT	25153	0.1			
6 Axle MT	6792	0			
7+ Axle MT	525	0	SUM	469487	0.027258803
User-Def	8153	0			
Unknown	47627	0.3	SUM	17223317	1

Census Station 49020 - I-80 - Summary Table - Vehicle Classification - Jan 1-Dec 31 03

Vehicle Class	# Vehicles	% Total			
Motorcycles	350619	0.7			
Cars	38316541	78.1			
2 Axle, 4T SU	7145444	14.6			
Bus	89324	0.2			
2 Axle,6T SU	1298060	2.6			
3 Axle SU	144614	0.3			
4+ Axle SU	2187	0			
< 4 Axle ST	143489	0.3			
5 Axle ST	1214187	2.5			
6+ Axle ST	13964	0			
< 5 Axle MT	122861	0.3			
6 Axle MT	19850	0			
7+ Axle MT	1294	0	SUM	1515645	0.030895362
User-Def	78495	0.2			
Unknown	116435	0.2	SUM	49057364	1

Census Station 49020 - I-80 - Summary Table - Vehicle Classification - Jan 1-Dec 31 07

Vehicle Class	# Vehicles	% Total				
Motorcycles	354737	0.8				
Cars	35512232	78.7				
2 Axle, 4T SU	6420680	14.2				
Bus	85591	0.2				
2 Axle,6T SU	1073625	2.4				
3 Axle SU	138259	0.3				
4+ Axle SU	2703	0				
< 4 Axle ST	127691	0.3				
5 Axle ST	1145782	2.5				
6+ Axle ST	12805	0				
< 5 Axle MT	100864	0.2				
6 Axle MT	18344	0				
7+ Axle MT	1144	0	SUM		1406630	0.031174782
User-Def	75138	0.2				
Unknown	51170	0.1	SUM		45120765	1

Census Station 49020 - I-80 - Summary Table - Vehicle Classification - Jan 1-Dec 31 08

Vehicle Class	# Vehicles	% Total				
Motorcycles	439979	0.7				
Cars	46801334	78.8				
2 Axle, 4T SU	8694841	14.6				
Bus	103334	0.2				
2 Axle,6T SU	1350570	2.3				
3 Axle SU	177309	0.3				
4+ Axle SU	4924	0				
< 4 Axle ST	157124	0.3				
5 Axle ST	1371960	2.3				
6+ Axle ST	16634	0				
< 5 Axle MT	119286	0.2			Cumulative	Ratios
6 Axle MT	20491	0				
7+ Axle MT	1340	0	SUM		1,686,835	0.028393663
User-Def	98768	0.2				
Unknown	50960	0.1	SUM		59,408,854	1

Census Station 49020 - I-80 - Summary Table - Vehicle Classification - Jan 1-Dec 31 09

I-680 Sheridan Road Interchange TEU-Qualified Trucks

Vehicle Class	# Vehicles	% Total			
Motorcycles	173706	1.1			
Cars	11954324	72.5			
2 Axle, 4T SU	3591997	21.8			
Bus	14350	0.1			
2 Axle,6T SU	253552	1.5			
3 Axle SU	32955	0.2			
4+ Axle SU	463	0			
< 4 Axle ST	53266	0.3			
5 Axle ST	298204	1.8			
6+ Axle ST	2268	0			
< 5 Axle MT	58595	0.4		Cumulative	Ratios
6 Axle MT	6398	0			
7+ Axle MT	586	0	SUM	419,317	0.02542028
User-Def	26226	0.2			
Unknown	28483	0.2	SUM	16,495,373	1

Census Station 49140 - I-680 - Summary Table - Vehicle Classification - Jan 1-Dec 31 06

I-880 Industrial Parkway TEU-Qualified Trucks

Vehicle Class	# Vehicles	% Total			
Motorcycles	2599	0			
Cars	24975956	82.7			
2 Axle, 4T SU	3272426	10.8			
Bus	13884	0			
2 Axle,6T SU	811891	2.7			
3 Axle SU	130490	0.4			
4+ Axle SU	4378	0			
< 4 Axle ST	197535	0.7			
5 Axle ST	623059	2.1			
6+ Axle ST	8595	0			
< 5 Axle MT	53776	0.2			
6 Axle MT	10061	0			
7+ Axle MT	1055	0	SUM	894081	0.029608422
User-Def	11409	0			
Unknown	79733	0.3	SUM	30196847	1

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 00

Vehicle Class	# Vehicles	% Total			
Motorcycles	123014	0.5			
Cars	17758234	78.3			
2 Axle, 4T SU	3574579	15.8			
Bus	18791	0.1			
2 Axle,6T SU	515206	2.3			
3 Axle SU	62403	0.3			
4+ Axle SU	1695	0			
< 4 Axle ST	101744	0.4			
5 Axle ST	432304	1.9			
6+ Axle ST	5438	0			
< 5 Axle MT	45095	0.2			
6 Axle MT	5971	0			
7+ Axle MT	540	0	SUM	591092	0.026060578
User-Def	18087	0.1			
Unknown	18361	0.1	SUM	22681462	1

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 03

Vehicle Class	# Vehicles	% Total			
Motorcycles	168770	0.5			
Cars	23823160	74.6			
2 Axle, 4T SU	6107917	19.1			
Bus	27879	0.1			
2 Axle,6T SU	820240	2.6			
3 Axle SU	90853	0.3			
4+ Axle SU	3112	0			
< 4 Axle ST	146044	0.5			
5 Axle ST	610899	1.9			
6+ Axle ST	6586	0			
< 5 Axle MT	63266	0.2			
6 Axle MT	8849	0			
7+ Axle MT	818	0	SUM	836462	0.026194598
User-Def	26986	0.1			
Unknown	27235	0.1	SUM	31932614	1

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 04

Vehicle Class	# Vehicles	% Total			
Motorcycles	190607	0.5			
Cars	27988436	70.5			
2 Axle, 4T SU	9222671	23.2			
Bus	44055	0.1			
2 Axle,6T SU	1043556	2.6			
3 Axle SU	110260	0.3			
4+ Axle SU	4063	0			
< 4 Axle ST	180689	0.5			
5 Axle ST	783912	2			
6+ Axle ST	7603	0			
< 5 Axle MT	73402	0.2			
6 Axle MT	9909	0			
7+ Axle MT	996	0	SUM	1056511	0.026594801
User-Def	36806	0.1			
Unknown	29258	0.1	SUM	39726223	1

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 05

Vehicle Class	# Vehicles	% Total			
Motorcycles	270079	0.5			
Cars	35293025	69.7			
2 Axle, 4T SU	12190980	24.1			
Bus	63663	0.1			
2 Axle,6T SU	1314350	2.6			
3 Axle SU	138747	0.3			
4+ Axle SU	5995	0			
< 4 Axle ST	224388	0.4			
5 Axle ST	948075	1.9			
6+ Axle ST	8695	0			
< 5 Axle MT	88436	0.2			
6 Axle MT	11016	0			
7+ Axle MT	1095	0	SUM	1281705	0.02530854
User-Def	47467	0.1			
Unknown	37171	0.1	SUM	50643182	1

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 06

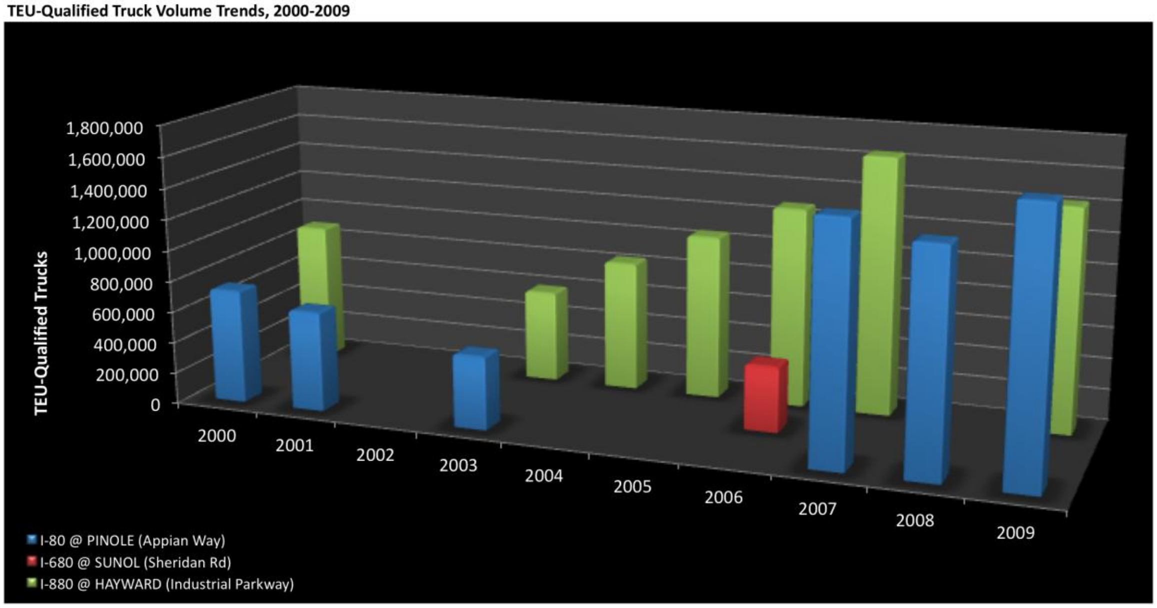
Vehicle Class	# Vehicles	% Total			
Motorcycles	346141	0.5			
Cars	48549053	74.6			
2 Axle, 4T SU	12337007	18.9			
Bus	84551	0.1			
2 Axle,6T SU	1824274	2.8			
3 Axle SU	194450	0.3			
4+ Axle SU	8430	0			
< 4 Axle ST	283954	0.4			
5 Axle ST	1228312	1.9			
6+ Axle ST	11278	0			
< 5 Axle MT	111232	0.2			
6 Axle MT	13243	0			
7+ Axle MT	1269	0	SUM	1649288	0.025332825
User-Def	60238	0.1			
Unknown	51347	0.1	SUM	65104779	1

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 07

Vehicle Class	# Vehicles	% Total			
Motorcycles	337680	0.5			
Cars	49822055	77.8			
2 Axle, 4T SU	10264147	16			
Bus	84074	0.1			
2 Axle,6T SU	1804967	2.8			
3 Axle SU	182846	0.3			
4+ Axle SU	6788	0			
< 4 Axle ST	254366	0.4			
5 Axle ST	1074380	1.7			
6+ Axle ST	8570	0			
< 5 Axle MT	74686	0.1			
6 Axle MT	10887	0			
7+ Axle MT	895	0	SUM	1423784	0.022236572
User-Def	54799	0.1			
Unknown	47794	0.1	SUM	64028934	1

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 09

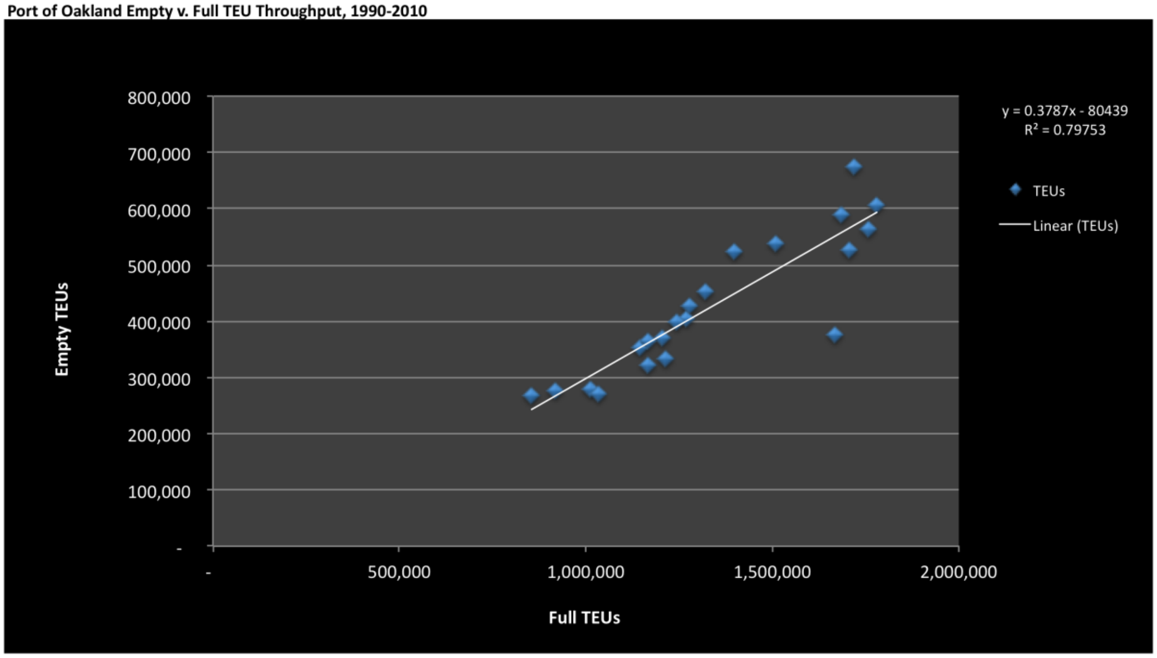
TEU-Qualified Truck Volume Trends, 2000-2009



4.3. Inferred Results

Container Throughput

Port of Oakland Empty v. Full TEU Throughput, 1990-2010

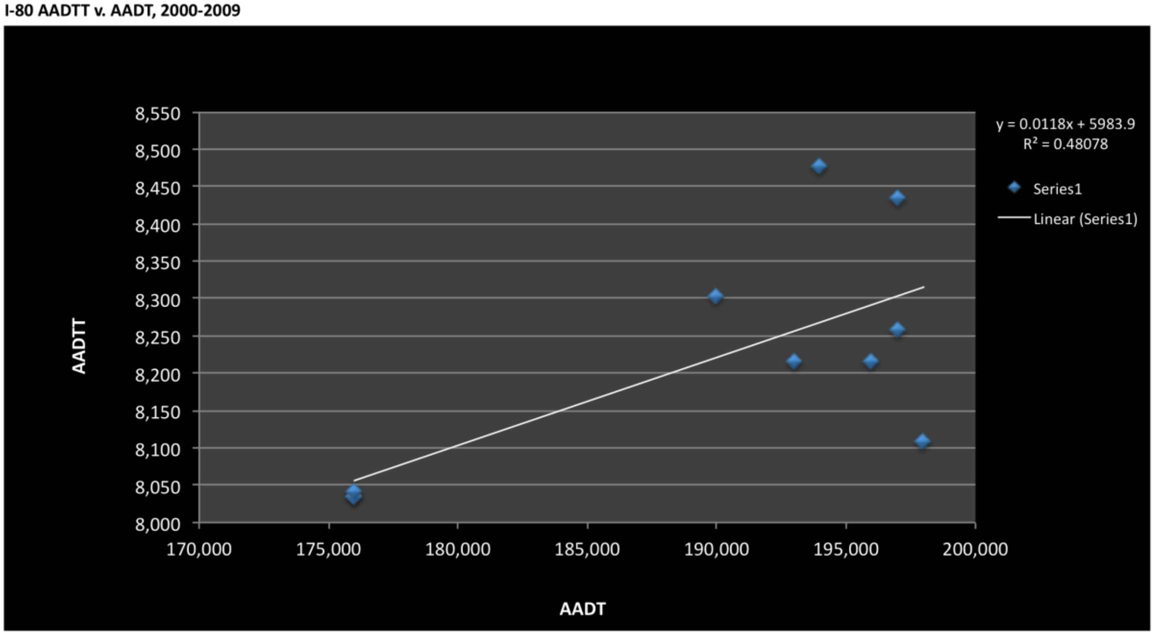


AADTT v. AADTs

I-80 AADTT v. AADT, 2000-2009

	X	Y
	AADT	**AADTT**
2000	176,000	8,036
2001	176,000	8,036
2002	176,000	8,041
2003	193,000	8,216
2004	197,000	8,259
2005	196,000	8,216
2006	197,000	8,434
2007	**198,000**	8,109
2008	194,000	8,478
2009	190,000	8,303
difference	***14,000***	***267***
% change	***7.95%***	***3.32%***
elasticity	***2.3941***	

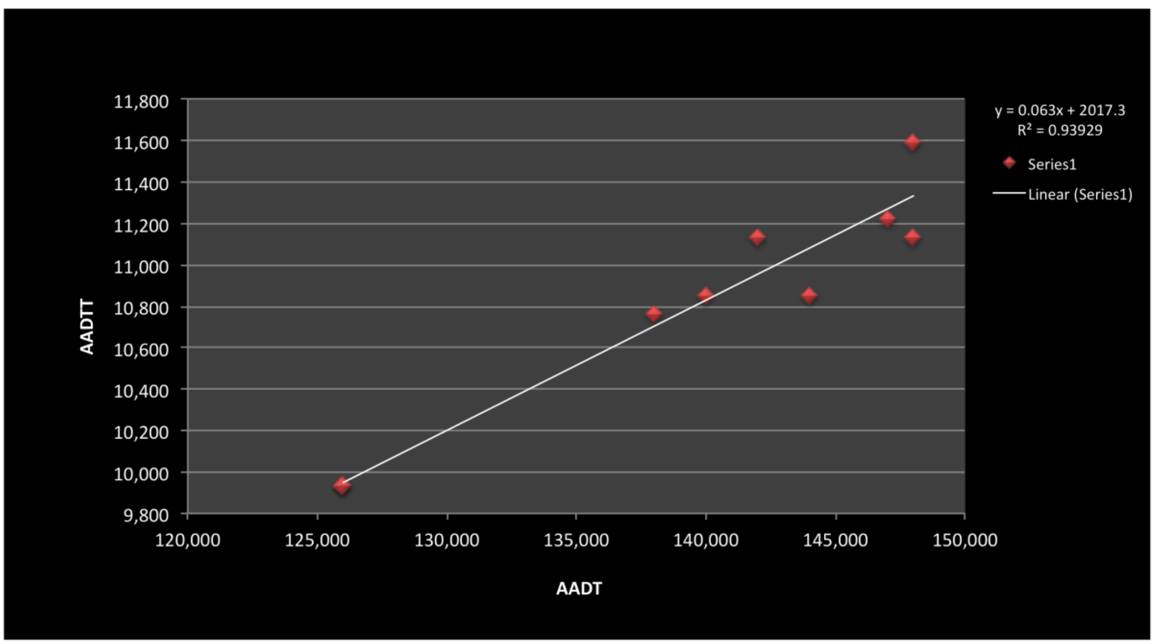
I-80 AADTT v. AADT, 2000-2009



I-680 AADTT v. AADT, 2000-2009

	X AADT	Y AADTT
2000	126,000	9,936
2001	126,000	9,936
2002	126,000	9,936
2003	144,000	10,856
2004	148,000	11,132
2005	147,000	11,224
2006	148,000	11,592
2007	142,000	11,132
2008	138,000	10,764
2009	140,000	10,856
difference	***14,000***	***920***
% change	***11.11%***	***9.26%***
elasticity	***1.2000***	

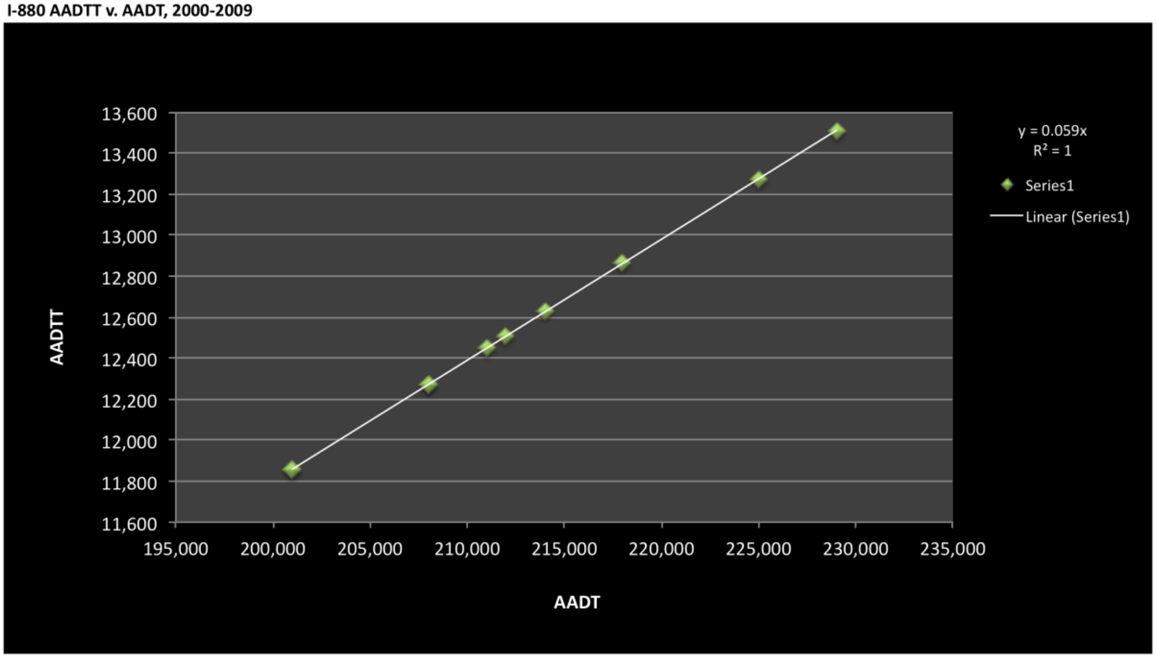
I-680 AADTT v. AADT, 2000-2009



I-880 AADTT v. AADT, 2000-2009

	X	Y
	AADT	**AADTT**
2000	201,000	11,859
2001	201,000	11,859
2002	208,000	12,272
2003	208,000	12,272
2004	212,000	12,508
2005	225,000	13,275
2006	229,000	13,511
2007	218,000	12,862
2008	214,000	12,626
2009	211,000	12,449
difference	***10,000***	***590***
% change	***4.98%***	***4.98%***
elasticity	***1.0000***	

I-880 AADTT v. AADT, 2000-2009

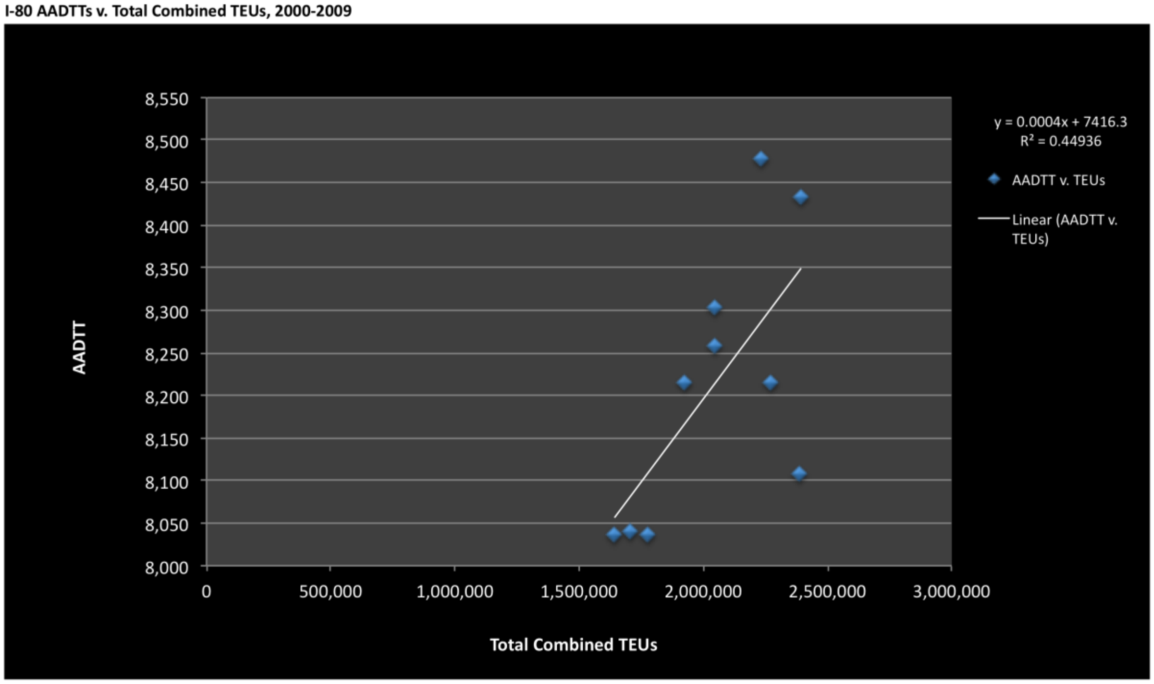


AADTTs v. TEUs

I-80 AADTT v. Total Combined TEUs, 2000-2009

	X	Y
	Total Combined	AADTT
2000	1,776,922	8,036
2001	1,643,585	8,036
2002	1,707,827	8,041
2003	1,923,104	8,216
2004	2,047,504	8,259
2005	2,273,990	8,216
2006	2,391,745	8,434
2007	2,387,911	8,109
2008	2,233,533	8,478
2009	2,045,211	8,303
difference	*268,289*	*267*
% change	*15.10%*	*3.32%*
elasticity	*4.5443*	

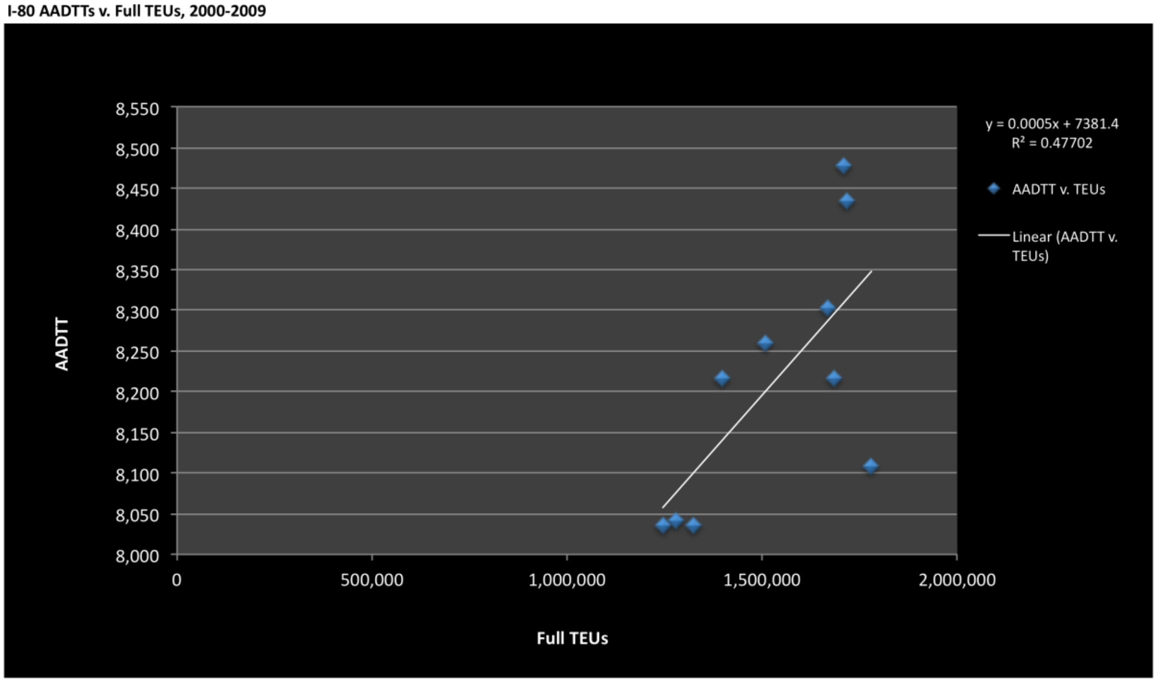
I-80 AADTTs v. Total Combined TEUs, 2000-2009



I-80 AADTT v. Full TEUs, 2000-2009

	X	Y
	Full	**AADTT**
2000	1,322,379	8,036
2001	1,245,347	8,036
2002	1,279,767	8,041
2003	1,398,958	8,216
2004	1,508,030	8,259
2005	1,682,837	8,216
2006	1,717,923	8,434
2007	1,779,917	8,109
2008	1,707,104	8,478
2009	1,668,383	8,303
difference	***346,004***	***267***
% change	***26.17%***	***3.32%***
elasticity	***7.8751***	

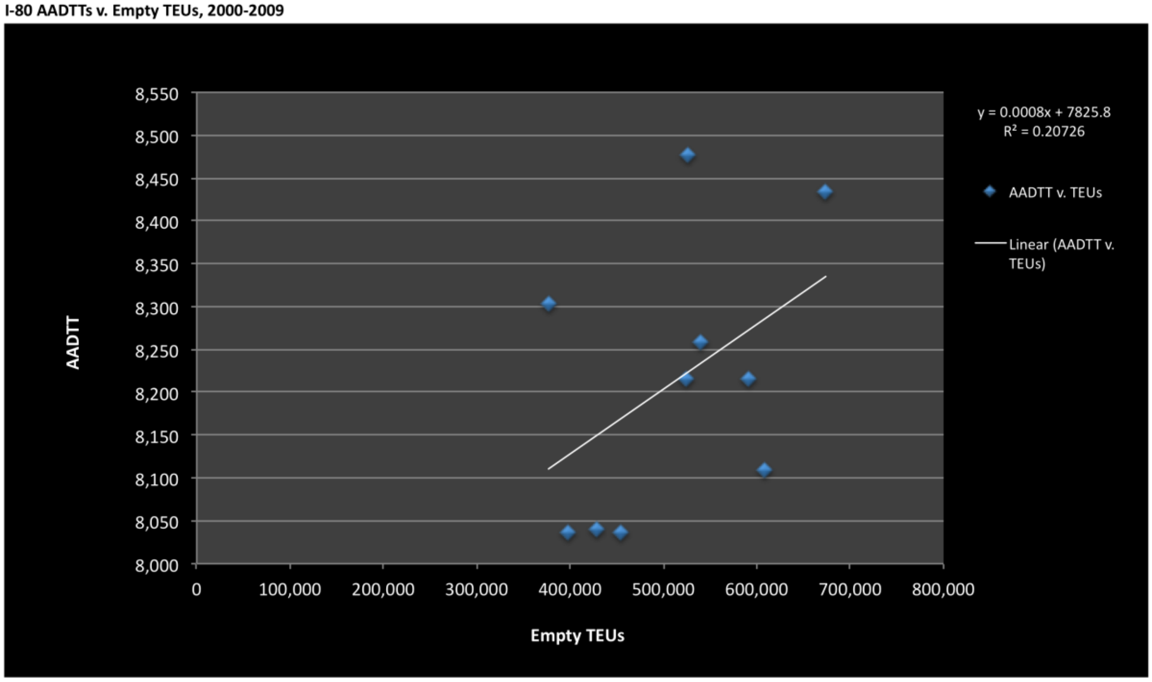
I-80 AADTTs v. Full TEUs, 2000-2009



I-80 AADTT v. Empty TEUs, 2000-2009

	X	Y
	Empty	**AADTT**
2000	454,543	8,036
2001	398,238	8,036
2002	428,060	8,041
2003	524,146	8,216
2004	539,474	8,259
2005	591,153	8,216
2006	673,822	8,434
2007	607,994	8,109
2008	526,429	8,478
2009	376,828	8,303
difference	***(77,715)***	***267***
% change	***-17.10%***	***3.32%***
elasticity	***-5.1459***	

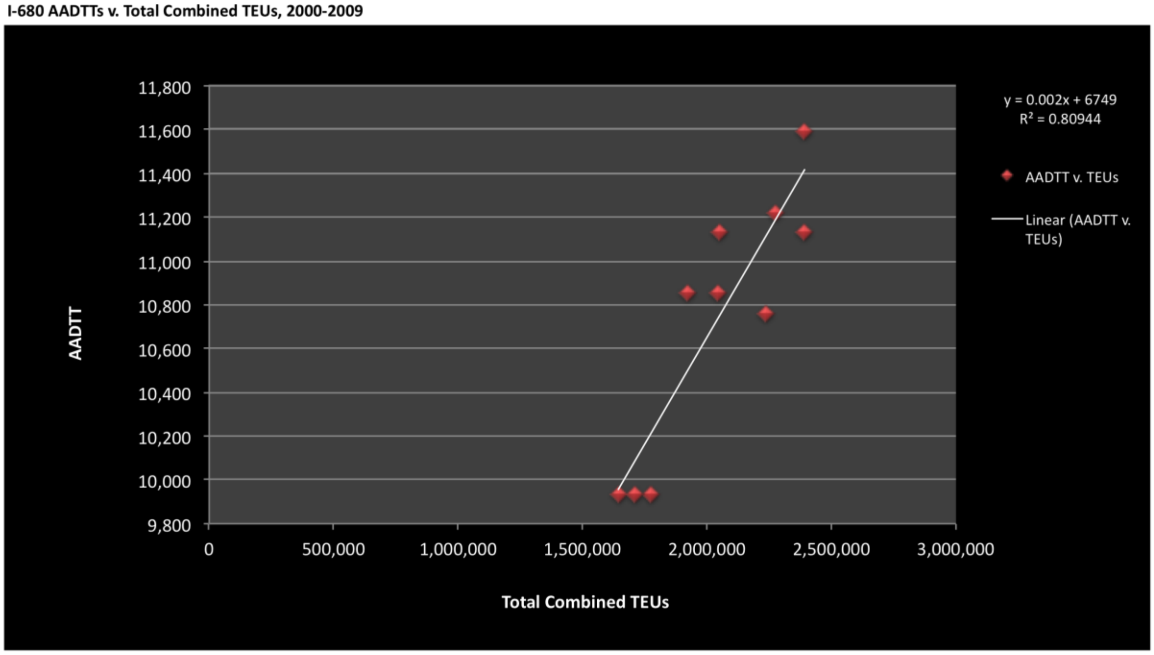
I-80 AADTTs v. Empty TEUs, 2000-2009



I-680 AADTT v. Total Combined TEUs, 2000-200

	X Total Combined	Y AADTT
2000	1,776,922	9,936
2001	1,643,585	9,936
2002	1,707,827	9,936
2003	1,923,104	10,856
2004	2,047,504	11,132
2005	2,273,990	11,224
2006	2,391,745	11,592
2007	2,387,911	11,132
2008	2,233,533	10,764
2009	2,045,211	10,856
difference	*268,289*	*920*
% change	*15.10%*	*9.26%*
elasticity	*1.6306*	

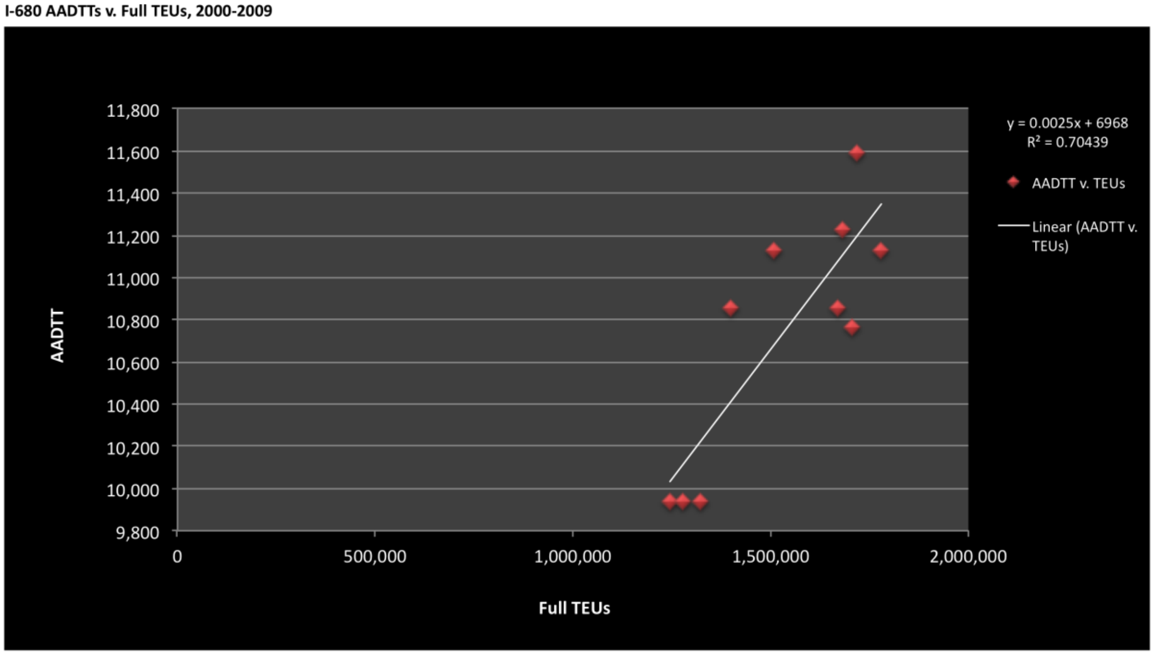
I-680 AADTTs v. Total Combined TEUs, 2000-2009



I-680 AADTT v. Full TEUs, 2000-2009

	X	Y
	Full	**AADTT**
2000	1,322,379	9,936
2001	1,245,347	9,936
2002	1,279,767	9,936
2003	1,398,958	10,856
2004	1,508,030	11,132
2005	1,682,837	11,224
2006	1,717,923	11,592
2007	1,779,917	11,132
2008	1,707,104	10,764
2009	1,668,383	10,856
difference	***346,004***	***920***
% change	***26.17%***	***9.26%***
elasticity	***2.8258***	

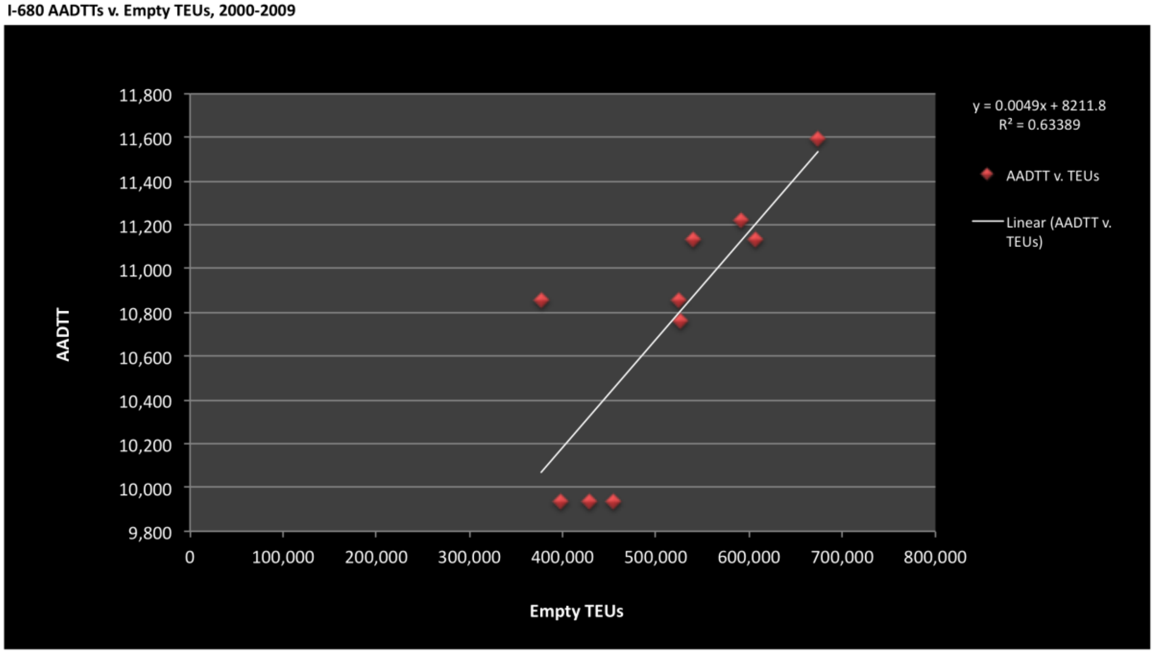
I-680 AADTTs v. Full TEUs, 2000-2009



I-680 AADTTs v. Empty TEUs, 2000-2009

	X	Y
	Empty	**AADTT**
2000	454,543	9,936
2001	398,238	9,936
2002	428,060	9,936
2003	524,146	10,856
2004	539,474	11,132
2005	591,153	11,224
2006	673,822	11,592
2007	607,994	11,132
2008	526,429	10,764
2009	376,828	10,856
difference	***(77,715)***	***920***
% change	***-17.10%***	***9.26%***
elasticity	***-1.8465***	

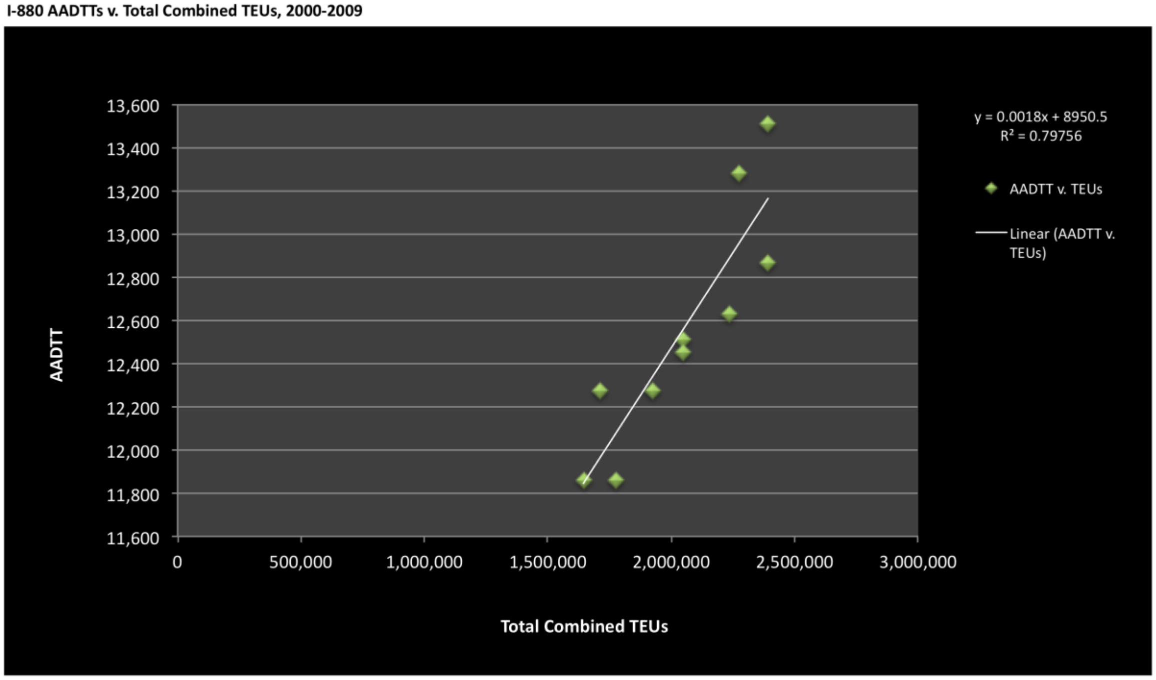
I-680 AADTTs v. Empty TEUs, 2000-2009



I-880 AADTT v. Total Combined TEUs, 2000-200

	X	Y
	Total Combined	AADTT
2000	1,776,922	11,859
2001	1,643,585	11,859
2002	1,707,827	12,272
2003	1,923,104	12,272
2004	2,047,504	12,508
2005	2,273,990	13,275
2006	2,391,745	13,511
2007	2,387,911	12,862
2008	2,233,533	12,626
2009	2,045,211	12,449
difference	*268,289*	*590*
% change	*15.10%*	*4.98%*
elasticity	*3.0348*	

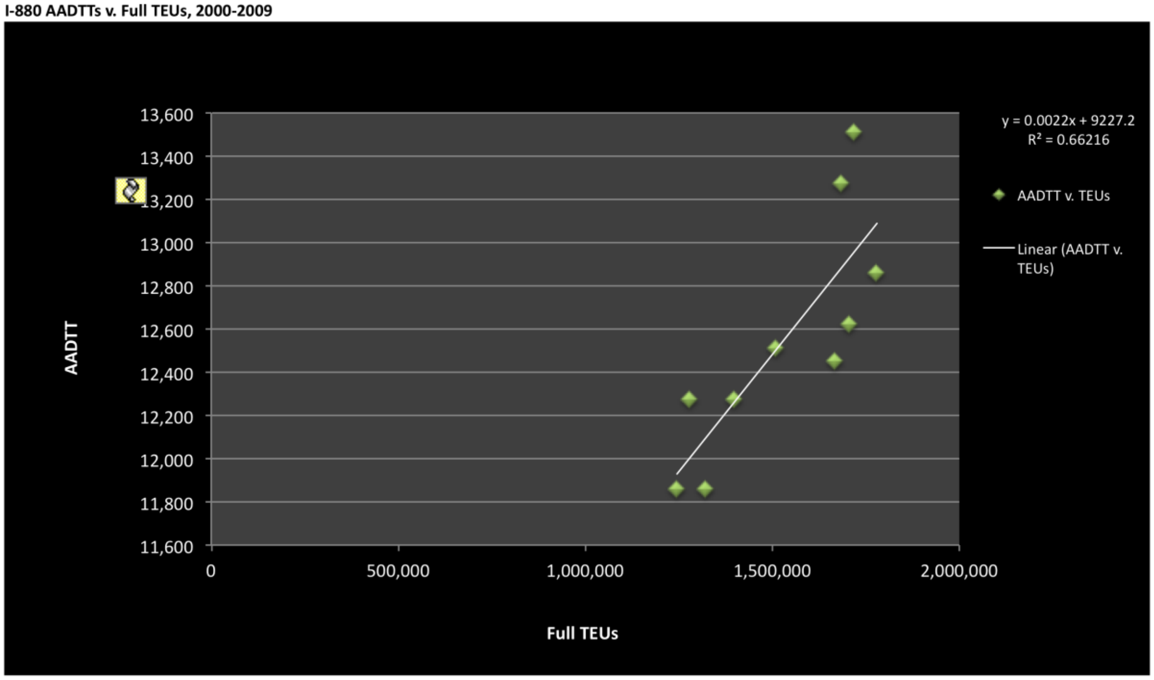
I-880 AADTTs v. Total Combined TEUs, 2000-2009



I-880 AADTT v. Full TEUs, 2000-2009

	X	Y
	Full	**AADTT**
2000	1,322,379	11,859
2001	1,245,347	11,859
2002	1,279,767	12,272
2003	1,398,958	12,272
2004	1,508,030	12,508
2005	1,682,837	13,275
2006	1,717,923	13,511
2007	1,779,917	12,862
2008	1,707,104	12,626
2009	1,668,383	12,449
difference	***346,004***	***590***
% change	***26.17%***	***4.98%***
elasticity	***5.2592***	

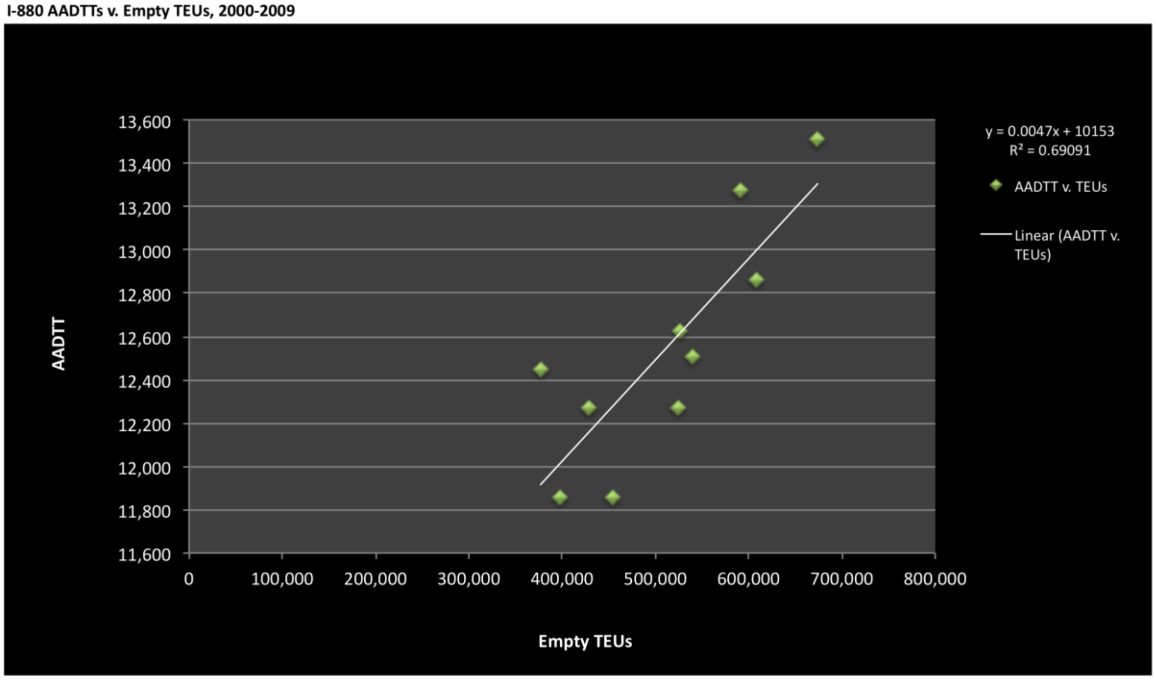
I-880 AADTTs v. Full TEUs, 2000-2009



I-880 AADTTs v. Empty TEUs, 2000-2009

	X	Y
	Empty	**AADTT**
2000	454,543	11,859
2001	398,238	11,859
2002	428,060	12,272
2003	524,146	12,272
2004	539,474	12,508
2005	591,153	13,275
2006	673,822	13,511
2007	607,994	12,862
2008	526,429	12,626
2009	376,828	12,449
difference	***(77,715)***	***590***
% change	***-17.10%***	***4.98%***
elasticity	***-3.4366***	

I-880 AADTTs v. Empty TEUs, 2000-2009

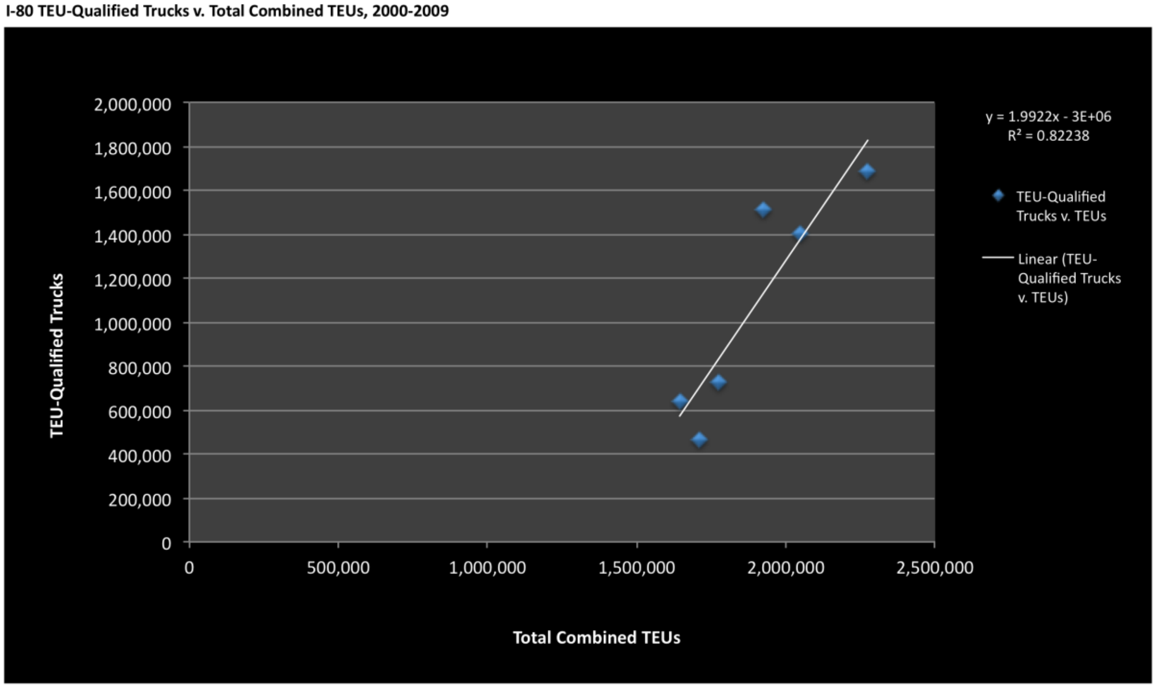


TEU-Qualified trucks v. TEUs

I-80 TEU-Qualified Trucks v. Total Combined TEUs, 2000-2009

	X	Y
	Total Combined TEUs	TEU-Qualified Trucks
2000	1,776,922	730,744
2001	1,643,585	642,508
2002	1,707,827	
2003	1,923,104	469,487
2004	2,047,504	
2005	2,273,990	
2006	2,391,745	
2007	2,387,911	1,515,645
2008	2,233,533	1,406,630
2009	2,045,211	1,686,835
difference	*268,289*	*956,091*
% change	*15.10%*	*130.84%*
elasticity	*0.1154*	

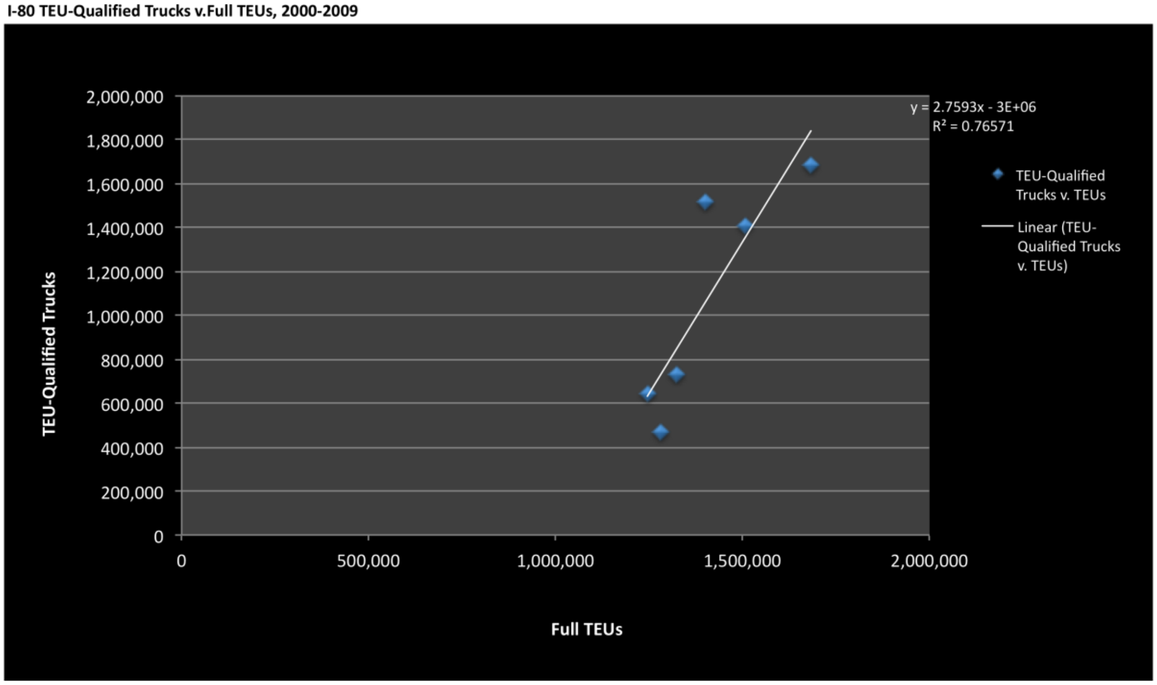
I-80 TEU-Qualified Trucks v. Total Combined TEUs, 2000-2009



I-80 TEU-Qualified Trucks v.Full TEUs, 2000-2009

	X	Y
	Full TEUs	**TEU-Qualified Trucks**
2000	1,322,379	730,744
2001	1,245,347	642,508
2002	1,279,767	
2003	1,398,958	469,487
2004	1,508,030	
2005	1,682,837	
2006	1,717,923	
2007	1,779,917	1,515,645
2008	1,707,104	1,406,630
2009	1,668,383	1,686,835
difference	***346,004***	***956,091***
% change	***26.17%***	***130.84%***
elasticity	***0.2000***	

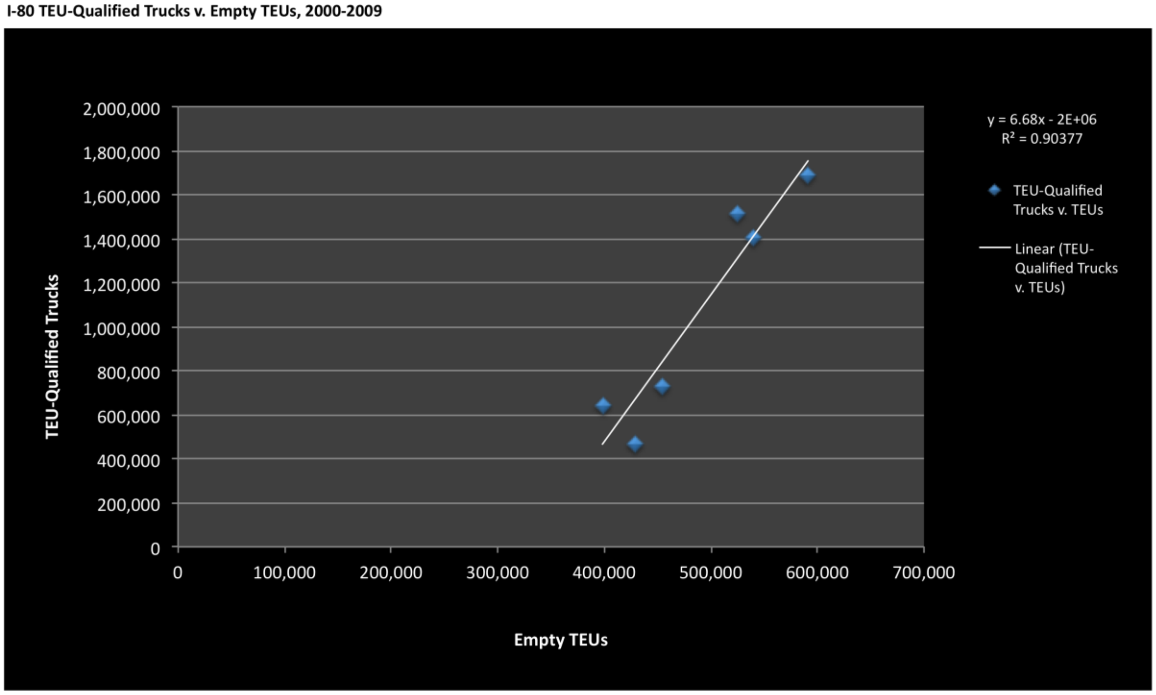
I-80 TEU-Qualified Trucks v.Full TEUs, 2000-2009



I-80 TEU-Qualified Trucks v. Empty TEUs, 2000-2009

	X	Y
	Empty TEUs	**TEU-Qualified Trucks**
2000	454,543	730,744
2001	398,238	642,508
2002	428,060	
2003	524,146	469,487
2004	539,474	
2005	591,153	
2006	673,822	
2007	607,994	1,515,645
2008	526,429	1,406,630
2009	376,828	1,686,835
difference	***(77,715)***	***956,091***
% change	***-17.10%***	***130.84%***
elasticity	***-0.1307***	

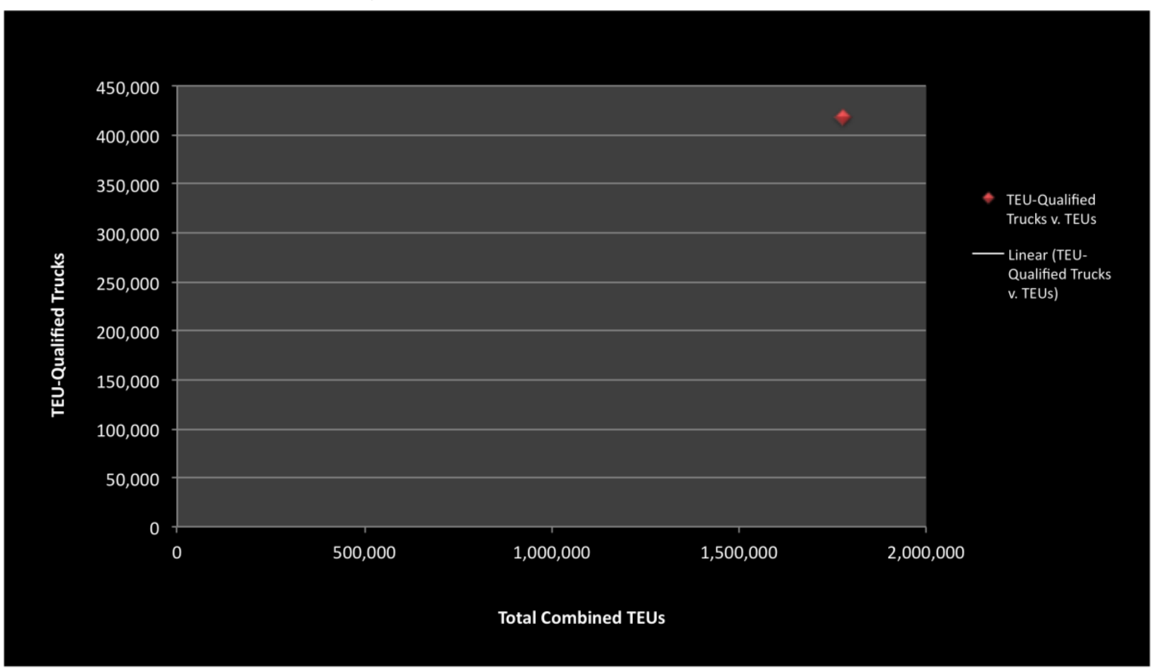
I-80 TEU-Qualified Trucks v. Empty TEUs, 2000-2009



I-680 TEU-Qualified Trucks v. Total Combined TEUs, 2000-2009

	X	Y
	Total Combined TEUs	**TEU-Qualified Trucks**
2000	1,776,922	
2001	1,643,585	
2002	1,707,827	
2003	1,923,104	
2004	2,047,504	
2005	2,273,990	
2006	***2,391,745***	***419,317***
2007	2,387,911	
2008	2,233,533	
2009	2,045,211	
difference	***268,289***	***-***
% change	***15.10%***	***-***
elasticity	***-***	

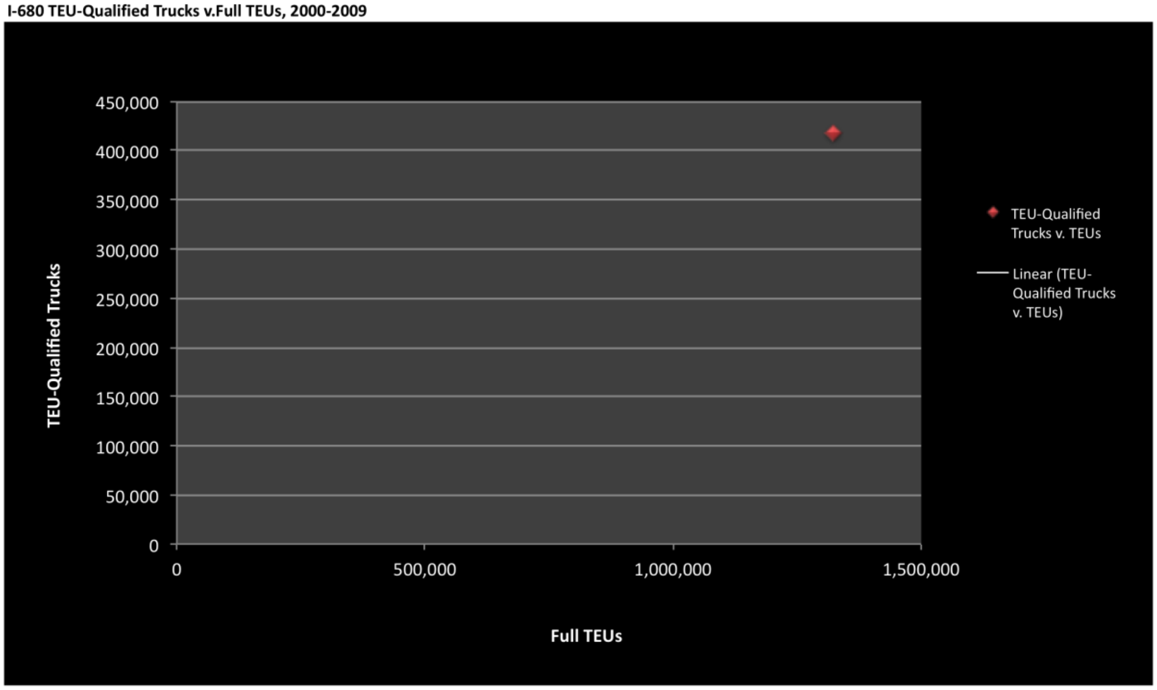
I-680 TEU-Qualified Trucks v. Total Combined TEUs, 2000-2009



I-680 TEU-Qualified Trucks v.Full TEUs, 2000-2009

	X	Y
	Full TEUs	TEU-Qualified Trucks
2000	1,322,379	
2001	1,245,347	
2002	1,279,767	
2003	1,398,958	
2004	1,508,030	
2005	1,682,837	
2006	***1,717,923***	***419,317***
2007	1,779,917	
2008	1,707,104	
2009	1,668,383	
difference	***346,004***	-
% change	***26.17%***	-
elasticity	-	

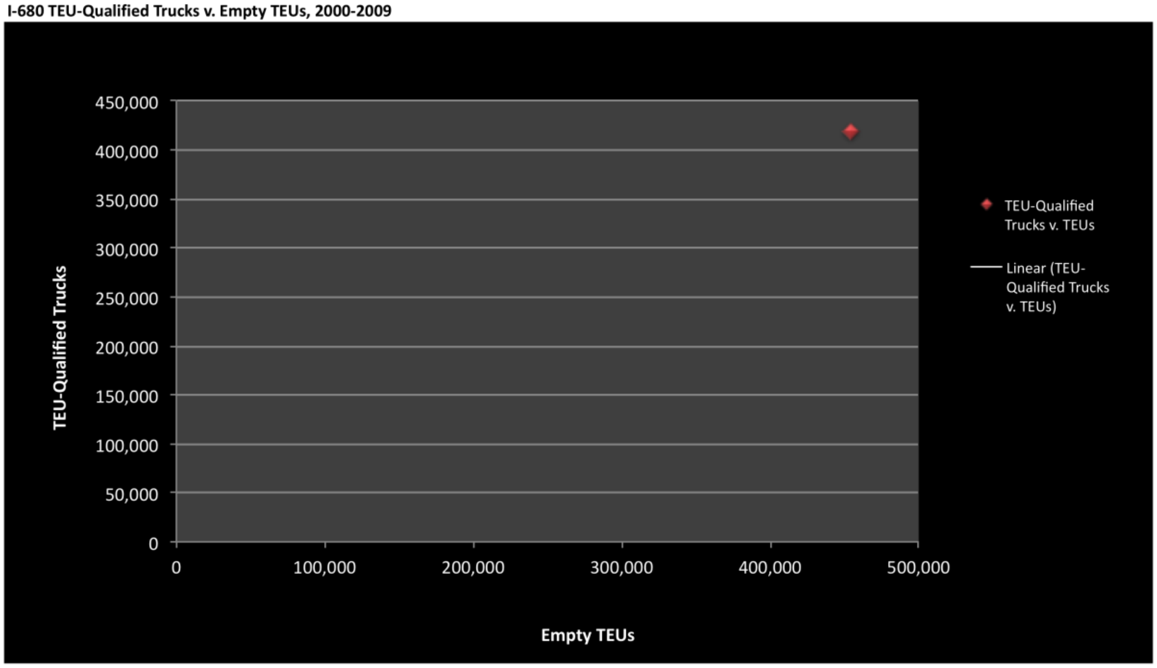
I-680 TEU-Qualified Trucks v.Full TEUs, 2000-2009



I-680 TEU-Qualified Trucks v. Empty TEUs, 2000-2009

	X	Y
	Empty TEUs	TEU-Qualified Trucks
2000	454,543	
2001	398,238	
2002	428,060	
2003	524,146	
2004	539,474	
2005	591,153	
2006	***673,822***	***419,317***
2007	607,994	
2008	526,429	
2009	376,828	
difference	***(77,715)***	-
% change	***-17.10%***	-
elasticity	-	

I-680 TEU-Qualified Trucks v. Empty TEUs, 2000-2009



4.4. Pavement Impact Estimation

<u>TI Calculations</u>

I-80 Appian Way

Vehicle Class	# Vehicles	% Total								
Motorcycles	1030	0								
Cars	18729776	80.1								
2 Axle, 4T SU	3207833	13.7								
Bus	50966	0.2								
2 Axle,6T SU	486852	2.1				*4-Lane TI*				
3 Axle SU	108154	0.5						Lanes		
			10 yr ESAL							
4+ Axle SU	330	0	Constant	Cumulative ESAL		1	2	3	4	Total
< 4 Axle ST	108417	0.5	1,840	199,487,280		13.95580809	13.95580809	16.45887427	16.45887427	60.82936473
5 Axle ST	560570	2.4	6,890	3,862,327,300		19.85638198	19.85638198	23.41775498	23.41775498	86.54827391
6+ Axle ST	8216	0	6,890	56,608,240		12.01317373	12.01317373	14.16781563	14.16781563	52.36197871
< 5 Axle MT	42878	0.2	6,890	295,429,420		14.62342406	14.62342406	17.24623157	17.24623157	63.73931126
6 Axle MT	10043	0	6,890	69,196,270		12.30367692	12.30367692	14.51042248	14.51042248	53.62819879
7+ Axle MT	620	0	6,890	4,271,800		8.832990785	8.832990785	10.41724591	10.41724591	38.5004734
User-Def	13199	0.1		4,487,320,310	SUM	81.58545556	81.58545556	96.21834484	96.21834484	355.6076008
Unknown	62938	0.3								
					AVG	14.81698337		5-Axle AVG	21.63706848	

Census Station 49020 - I-80 - Summary Table - Vehicle Classification - Jan 1-Dec 31 00

Vehicle Class	# Vehicles	% Total								
Motorcycles	761	0								
Cars	17477423	79.8								
2 Axle, 4T SU	3088931	14.1								
Bus	47558	0.2								
2 Axle,6T SU	480087	2.2				*4-Lane TI*				
3 Axle SU	102768	0.5						Lanes		
			10 yr ESAL							
4+ Axle SU	692	0	Constant	Cumulative ESAL		1	2	3	4	Total
< 4 Axle ST	98107	0.4	1,840	180,516,880		13.79083935	13.79083935	16.2643173	16.2643173	60.1103133
5 Axle ST	490254	2.2	6,890	3,377,850,060		19.54219231	19.54219231	23.04721332	23.04721332	85.17881126
6+ Axle ST	7662	0	6,890	52,791,180		11.91378839	11.91378839	14.05060487	14.05060487	51.92878652
< 5 Axle MT	36058	0.2	6,890	248,439,620		14.32505707	14.32505707	16.89435049	16.89435049	62.43881512
6 Axle MT	9809	0	6,890	67,584,010		12.26920745	12.26920745	14.46977069	14.46977069	53.47795629
7+ Axle MT	618	0	6,890	4,258,020		8.829595229	8.829595229	10.41324134	10.41324134	38.48567314
User-Def	11677	0.1		3,931,439,770	SUM	80.67067979	80.67067979	95.13949802	95.13949802	351.6203556
Unknown	59688	0.3								
					AVG	14.65084815		5-Axle AVG	21.29470282	

Census Station 49020 - I-80 - Summary Table - Vehicle Classification - Jan 1-Dec 31 01

Vehicle Class	# Vehicles	% Total								
Motorcycles	509	0								
Cars	13646885	79.2								
2 Axle, 4T SU	2543867	14.8								
Bus	35765	0.2								
2 Axle,6T SU	394205	2.3				*4-Lane TI*				
3 Axle SU	74779	0.4						Lanes		
			10 yr ESAL							
4+ Axle SU	2040	0	Constant	Cumulative ESAL		1	2	3	4	Total
< 4 Axle ST	69807	0.4	1,840	128,444,880		13.24348786	13.24348786	15.61879471	15.61879471	57.72456515
5 Axle ST	361325	2.1	6,890	2,489,529,250		18.84529888	18.84529888	22.22532747	22.22532747	82.14125271
6+ Axle ST	5885	0	6,890	40,547,650		11.54550665	11.54550665	13.61626938	13.61626938	50.32355208
< 5 Axle MT	25153	0.1	6,890	173,304,170		13.72408349	13.72408349	16.18558834	16.18558834	59.81934366
6 Axle MT	6792	0	6,890	46,796,880		11.74413108	11.74413108	13.85051841	13.85051841	51.18929898
7+ Axle MT	525	0	6,890	3,617,250		8.659884973	8.659884973	10.21309243	10.21309243	37.74595481
User-Def	8153	0		2,882,240,080	SUM	77.76239294	77.76239294	91.70959075	91.70959075	338.9439674
Unknown	47627	0.3								
					AVG	14.12266531		5-Axle AVG	20.53531318	

Census Station 49020 - I-80 - Summary Table - Vehicle Classification - Jan 1-Dec 31 03

4-Lane TI

Vehicle Class	# Vehicles	% Total	10 yr ESAL Constant	Cumulative ESAL		Lanes 1	2	3	4	Total
Motorcycles	350619	0.7								
Cars	38316541	78.1								
2 Axle, 4T SU	7145444	14.6								
Bus	89324	0.2								
2 Axle,6T SU	1298060	2.6								
3 Axle SU	144614	0.3								
4+ Axle SU	2187	0								
< 4 Axle ST	143489	0.3	1,840	264,019,760		14.42911897	14.42911897	17.01707658	17.01707658	62.89239111
5 Axle ST	1214187	2.5	6,890	8,365,748,430		21.76923413	21.76923413	25.67368978	25.67368978	94.8858478
6+ Axle ST	13964	0	6,890	96,211,960		12.7958558	12.7958558	15.09087689	15.09087689	55.77346539
< 5 Axle MT	122861	0.3	6,890	846,512,290		16.57499621	16.57499621	19.54783105	19.54783105	72.24565452
6 Axle MT	19850	0	6,890	136,766,500		13.3427905	13.3427905	15.73590794	15.73590794	58.15739688
7+ Axle MT	1294	0	6,890	8,915,660		9.641250019	9.641250019	11.37047177	11.37047177	42.02344357
User-Def	78495	0.2			SUM	88.55324563	88.55324563	104.435854	104.435854	385.9781993
Unknown	116435	0.2								
					AVG	16.08242497		5-Axle AVG	23.72146195	

Census Station 49020 - I-80 - Summary Table - Vehicle Classification - Jan 1-Dec 31 07

4-Lane TI

Vehicle Class	# Vehicles	% Total	10 yr ESAL Constant	Cumulative ESAL		Lanes 1	2	3	4	Total
Motorcycles	354737	0.8								
Cars	35512232	78.7								
2 Axle, 4T SU	6420680	14.2								
Bus	85591	0.2								
2 Axle,6T SU	1073625	2.4								
3 Axle SU	138259	0.3								
4+ Axle SU	2703	0								
< 4 Axle ST	127691	0.3	1,840	234,951,440		14.23021541	14.23021541	16.78249835	16.78249835	62.02542751
5 Axle ST	1145782	2.5	6,890	7,894,437,980		21.61953276	21.61953276	25.49713848	25.49713848	94.23334248
6+ Axle ST	12805	0	6,890	88,226,450		12.66459589	12.66459589	14.93607465	14.93607465	55.20134109
< 5 Axle MT	100864	0.2	6,890	694,952,960		16.19040723	16.19040723	19.0942635	19.0942635	70.56934147
6 Axle MT	18344	0	6,890	126,390,160		13.21809769	13.21809769	15.58885065	15.58885065	57.61389668
7+ Axle MT	1144	0	6,890	7,882,160		9.500924419	9.500924419	11.20497785	11.20497785	41.41180453
User-Def	75138	0.2			SUM	87.4237734	87.4237734	103.1038035	103.1038035	381.0551538
Unknown	51170	0.1								
					AVG	15.87729807		5-Axle AVG	23.55833562	

Census Station 49020 - I-80 - Summary Table - Vehicle Classification - Jan 1-Dec 31 08

4-Lane TI

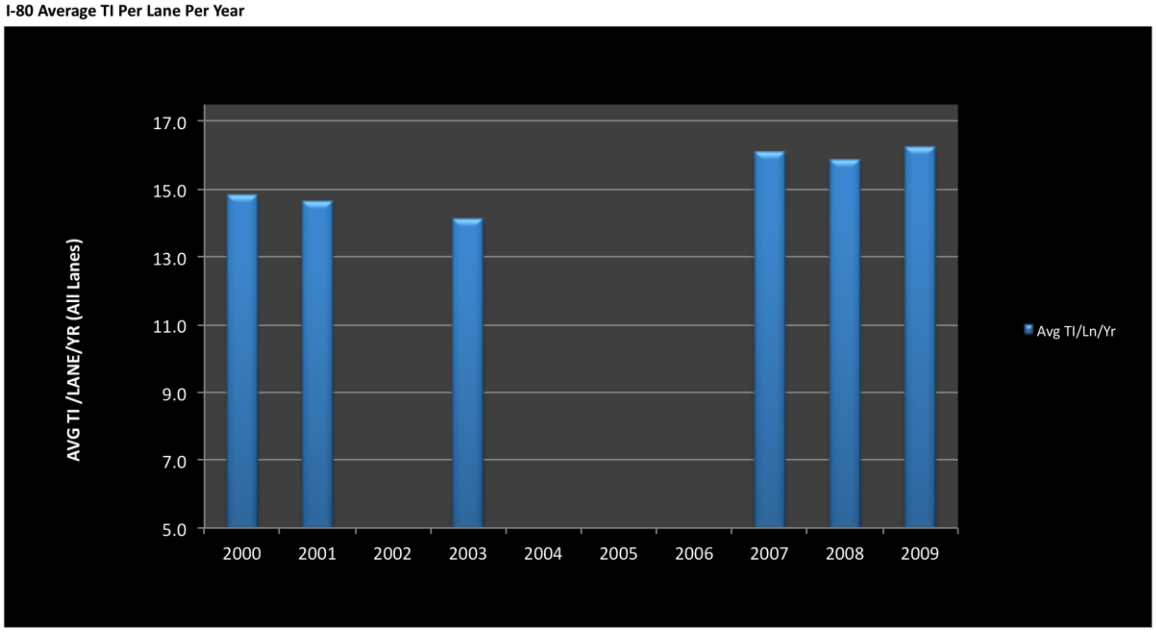
Vehicle Class	# Vehicles	% Total	10 yr ESAL Constant	Cumulative ESAL		Lanes 1	2	3	4	Total
Motorcycles	439979	0.7								
Cars	46801334	78.8								
2 Axle, 4T SU	8694841	14.6								
Bus	103334	0.2								
2 Axle,6T SU	1350570	2.3								
3 Axle SU	177309	0.3								
4+ Axle SU	4924	0								
< 4 Axle ST	157124	0.3	1,840	289,108,160		14.5858338	14.5858338	17.20189924	17.20189924	63.57546608
5 Axle ST	1371960	2.3	6,890	9,452,804,400		22.08802061	22.08802061	26.04965271	26.04965271	96.27534664
6+ Axle ST	16634	0	6,890	114,608,260		13.06507097	13.06507097	15.40837758	15.40837758	56.94689711
< 5 Axle MT	119286	0.2	6,890	821,880,540		16.51685339	16.51685339	19.47925993	19.47925993	71.99222665
6 Axle MT	20491	0	6,890	141,182,990		13.39334887	13.39334887	15.79553429	15.79553429	58.37776632
7+ Axle MT	1340	0	6,890	9,232,600		9.681410553	9.681410553	11.41783536	11.41783536	42.19849182
User-Def	98768	0.2			SUM	89.3305382	89.3305382	105.3525591	105.3525591	389.3661946
Unknown	50960	0.1								
					AVG	16.22359144		5-Axle AVG	24.06883666	

Census Station 49020 - I-80 - Summary Table - Vehicle Classification - Jan 1-Dec 31 09

I-80 Average TI Per Lane Per Year

	TI
2000	14.8170
2001	14.6508
2002	
2003	14.1227
2004	
2005	
2006	
2007	16.0824
2008	15.8773
2009	16.2236
Difference	***1.4066***
% Change	***9.49%***
Average	***15.2956***

I-80 Average TI Per Lane Per Year



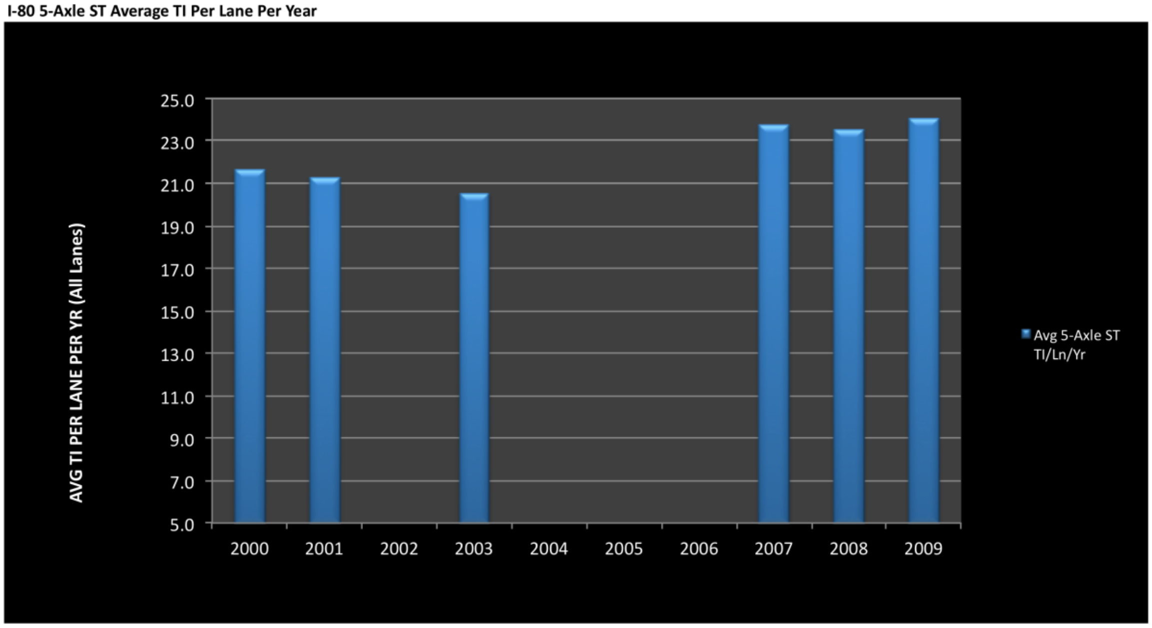
I-80 5-Axle ST TI Per Lane Per Year

	Lanes 1	2	3	4
2000	19.8564	19.8564	23.4178	23.4178
2001	19.5422	19.5422	23.0472	23.0472
2002				
2003	18.8453	18.8453	22.2253	22.2253
2004				
2005				
2006				
2007	21.7692	21.7692	25.6737	25.6737
2008	21.6195	21.6195	25.4971	25.4971
2009	22.0880	22.0880	26.0497	26.0497
Difference	*2.2316*	*2.2316*	*2.6319*	*2.6319*
% Change	*11.24%*	*11.24%*	*11.24%*	*11.24%*
Average	*20.6201*	*20.6201*	*24.3185*	*24.3185*
Overall Avg.		*22.4693*		

I-80 5-Axle ST Average TI Per Lane Per Year

	TI
2000	21.6371
2001	21.2947
2002	
2003	20.5353
2004	
2005	
2006	
2007	23.7215
2008	23.5583
2009	24.0688
Difference	***2.4318***
% Change	***11.24%***
Average	***22.4693***

I-80 5-Axle ST Average TI Per Lane Per Year



I-680 Sheridan Road Interchange

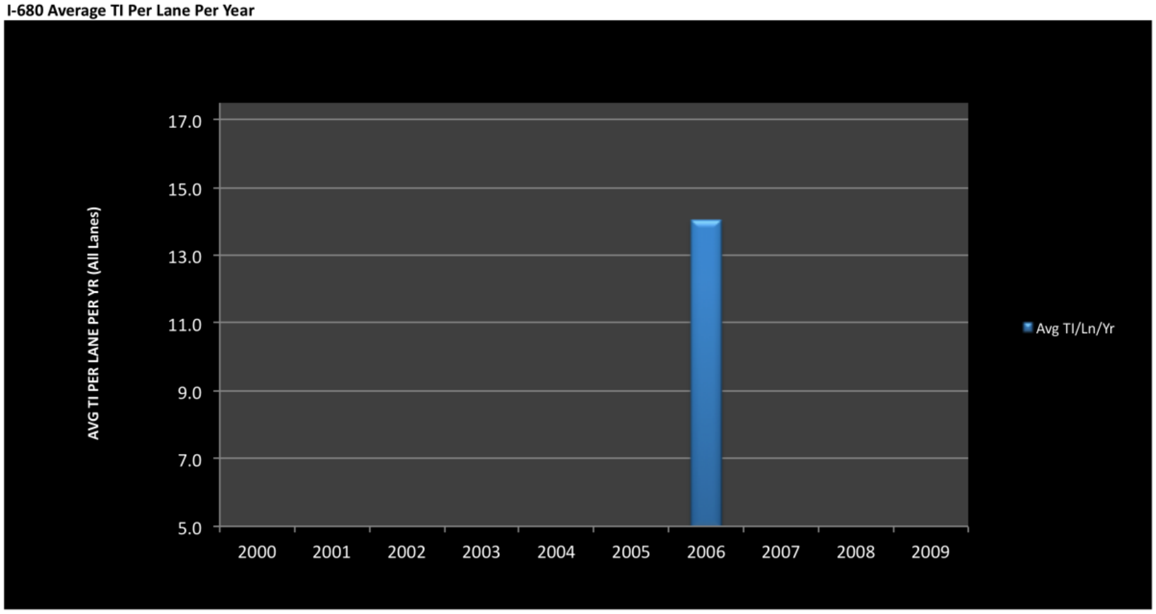
Vehicle Class	# Vehicles	% Total								
Motorcycles	173706	1.1								
Cars	11954324	72.5								
2 Axle, 4T SU	3591997	21.8								
Bus	14350	0.1								
2 Axle,6T SU	253552	1.5				***4-Lane TI***				
3 Axle SU	32955	0.2				Lanes				
			10 yr ESAL Constant	Cumulative ESAL						
4+ Axle SU	463	0				1	2	3	4	**Total**
< 4 Axle ST	53266	0.3	1,840	98,009,440		12.82407236	12.82407236	15.12415428	15.12415428	55.89645329
5 Axle ST	298204	1.8	6,890	2,054,625,560		18.41960313	18.41960313	21.72328038	21.72328038	80.28576702
6+ Axle ST	2268	0	6,890	15,626,520		10.30705727	10.30705727	12.15569594	12.15569594	44.92550643
< 5 Axle MT	58595	0.4	6,890	403,719,550		15.17709221	15.17709221	17.89920375	17.89920375	66.15259193
6 Axle MT	6398	0	6,890	44,082,220		11.66090965	11.66090965	13.75237067	13.75237067	50.82656063
7+ Axle MT	586	0	6,890	4,037,540		8.773906109	8.773906109	10.34756401	10.34756401	38.24294024
User-Def	26226	0.2		2,620,100,830	SUM	77.16264074	77.16264074	91.00226903	91.00226903	336.3298195
Unknown	28483	0.2								
					AVG	14.01374248		5-Axle AVG	20.07144175	

Census Station 49140 - I-680 - Summary Table - Vehicle Classification - Jan 1-Dec 31 06

I-680 Average TI Per Lane Per Year

	TI
2000	
2001	
2002	
2003	
2004	
2005	
2006	14.0137
2007	
2008	
2009	
Difference	-
% Change	-
Average	***14.0137***

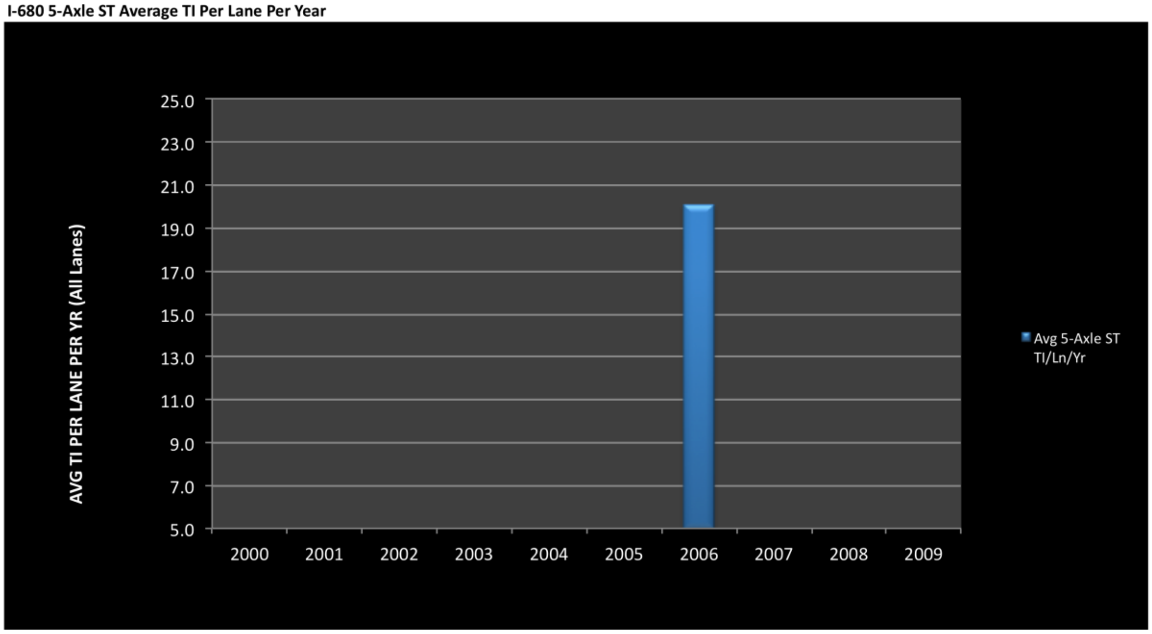
I-680 Average TI Per Lane Per Year



I-680 5-Axle ST Average TI Per Lane Per Year

	TI
2000	
2001	
2002	
2003	
2004	
2005	
2006	20.0714
2007	
2008	
2009	
Difference	*-*
% Change	*-*
Average	***20.0714***

I-680 5-Axle ST Average TI Per Lane Per Year



I-880 Industrial Pkway HOV LDF is neglible; trucks unauthorized to use HOVs (CA Driver Handbook, 2011)

4-Lane TI

Vehicle Class	# Vehicles	% Total	10 yr ESAL Constant	Cumulative ESAL		Lanes 1	2	3	4	Total
Motorcycles	2599	0								
Cars	24975956	82.7								
2 Axle, 4T SU	3272426	10.8								
Bus	13884	0								
2 Axle,6T SU	811891	2.7								
3 Axle SU	130490	0.4								
4+ Axle SU	4378	0								
< 4 Axle ST	197535	0.7	1,840	363,464,400		14.98856455	14.98856455	17.67686241	17.67686241	65.33085392
5 Axle ST	623059	2.1	6,890	4,292,876,510		20.107688	20.107688	23.7141344	23.7141344	87.64364482
6+ Axle ST	8595	0	6,890	59,219,550		12.07781648	12.07781648	14.24405248	14.24405248	52.64373792
< 5 Axle MT	53776	0.2	6,890	370,516,640		15.02287997	15.02287997	17.71733252	17.71733252	65.48042498
6 Axle MT	10061	0	6,890	69,320,290		12.30629901	12.30629901	14.51351486	14.51351486	53.63962775
7+ Axle MT	1055	0	6,890	7,268,950		9.409796017	9.409796017	11.09750496	11.09750496	41.01460196
User-Def	11409	0		5,162,666,340	SUM	83.91304403	83.91304403	98.96340165	98.96340165	365.7528914
Unknown	79733	0.3								
					AVG	15.23970381		5-Axle AVG	21.9109112	

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 00

4-Lane TI

Vehicle Class	# Vehicles	% Total	10 yr ESAL Constant	Cumulative ESAL		Lanes 1	2	3	4	Total
Motorcycles	123014	0.5								
Cars	17758234	78.3								
2 Axle, 4T SU	3574579	15.8								
Bus	18791	0.1								
2 Axle,6T SU	515206	2.3								
3 Axle SU	62403	0.3								
4+ Axle SU	1695	0								
< 4 Axle ST	101744	0.4	1,840	187,208,960		13.85070718	13.85070718	16.33492282	16.33492282	60.37126001
5 Axle ST	432304	1.9	6,890	2,978,574,560		19.25183308	19.25183308	22.70477626	22.70477626	83.91321867
6+ Axle ST	5438	0	6,890	37,467,820		11.43748221	11.43748221	13.48887004	13.48887004	49.8527045
< 5 Axle MT	45095	0.2	6,890	310,704,550		14.71141493	14.71141493	17.35000418	17.35000418	64.12283824
6 Axle MT	5971	0	6,890	41,140,190		11.56545619	11.56545619	13.639797	13.639797	50.41050638
7+ Axle MT	540	0	6,890	3,720,600		8.688964518	8.688964518	10.24738758	10.24738758	37.8727042
User-Def	18087	0.1		3,558,816,680	SUM	79.50585811	79.50585811	93.76575789	93.76575789	346.543232
Unknown	18361	0.1								
					AVG	14.43930133		5-Axle AVG	20.97830467	

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 03

4-Lane TI

Vehicle Class	# Vehicles	% Total	10 yr ESAL Constant	Cumulative ESAL		Lanes 1	2	3	4	Total
Motorcycles	168770	0.5								
Cars	23823160	74.6								
2 Axle, 4T SU	6107917	19.1								
Bus	27879	0.1								
2 Axle,6T SU	820240	2.6								
3 Axle SU	90853	0.3								
4+ Axle SU	3112	0								
< 4 Axle ST	146044	0.5	1,840	268,720,960		14.45945628	14.45945628	17.05285508	17.05285508	63.02462273
5 Axle ST	610899	1.9	6,890	4,209,094,110		20.06058191	20.06058191	23.65857951	23.65857951	87.43832284
6+ Axle ST	6586	0	6,890	45,377,540		11.7011663	11.7011663	13.79984762	13.79984762	51.00202783
< 5 Axle MT	63266	0.2	6,890	435,902,740		15.31624981	15.31624981	18.06332018	18.06332018	66.75913999
6 Axle MT	8849	0	6,890	60,969,610		12.1197476	12.1197476	14.29350423	14.29350423	52.82650366
7+ Axle MT	818	0	6,890	5,636,020		9.129159806	9.129159806	10.7665348	10.7665348	39.79138921
User-Def	26986	0.1			SUM	82.78636171	82.78636171	97.63464143	97.63464143	360.8420063
Unknown	27235	0.1								
					AVG	15.03508359		5-Axle AVG	21.85958071	

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 04

4-Lane TI

Vehicle Class	# Vehicles	% Total	10 yr ESAL Constant	Cumulative ESAL		Lanes 1	2	3	4	Total
Motorcycles	190607	0.5								
Cars	27988436	70.5								
2 Axle, 4T SU	9222671	23.2								
Bus	44055	0.1								
2 Axle,6T SU	1043556	2.6								
3 Axle SU	110260	0.3								
4+ Axle SU	4063	0								
< 4 Axle ST	180689	0.5	1,840	332,467,760		14.83041397	14.83041397	17.49034648	17.49034648	64.6415209
5 Axle ST	783912	2	6,890	5,401,153,680		20.66478906	20.66478906	24.37115521	24.37115521	90.07188854
6+ Axle ST	7603	0	6,890	52,384,670		11.90283409	11.90283409	14.03768585	14.03768585	51.88103989
< 5 Axle MT	73402	0.2	6,890	505,739,780		15.58950787	15.58950787	18.38558888	18.38558888	67.9501935
6 Axle MT	9909	0	6,890	68,273,010		12.28402569	12.28402569	14.48724667	14.48724667	53.54254472
7+ Axle MT	996	0	6,890	6,862,440		9.34557501	9.34557501	11.0217655	11.0217655	40.73468101
User-Def	36806	0.1			SUM	84.61714569	84.61714569	99.79378859	99.79378859	368.8218686
Unknown	29258	0.1								
					AVG	15.36757786		5-Axle AVG	22.51797213	

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 05

Vehicle Class	# Vehicles	% Total								
Motorcycles	270079	0.5								
Cars	35293025	69.7								
2 Axle, 4T SU	12190980	24.1								
Bus	63663	0.1								
2 Axle,6T SU	1314350	2.6				***4-Lane TI***				
3 Axle SU	138747	0.3				Lanes				
			10 yr ESAL	Cumulative						
4+ Axle SU	5995	0	Constant	ESAL		1	2	3	4	Total
< 4 Axle ST	224388	0.4	1,840	412,873,920		15.21764174	15.21764174	17.94702611	17.94702611	66.32933569
5 Axle ST	948075	1.9	6,890	6,532,236,750		21.13768623	21.13768623	24.92886961	24.92886961	92.13311168
6+ Axle ST	8695	0	6,890	59,908,550		12.09445344	12.09445344	14.2636734	14.2636734	52.71625369
< 5 Axle MT	88436	0.2	6,890	609,324,040		15.93903514	15.93903514	18.79780617	18.79780617	69.47368262
6 Axle MT	11016	0	6,890	75,900,240		12.43981763	12.43981763	14.67098093	14.67098093	54.22159713
7+ Axle MT	1095	0	6,890	7,544,550		9.451558931	9.451558931	11.14675833	11.14675833	41.19663453
User-Def	47467	0.1			SUM	86.28019313	86.28019313	101.7551145	101.7551145	376.0706153
Unknown	37171	0.1								
					AVG	15.66960897		5-Axle AVG	23.03327792	

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 06

Vehicle Class	# Vehicles	% Total								
Motorcycles	346141	0.5								
Cars	48549053	74.6								
2 Axle, 4T SU	12337007	18.9								
Bus	84551	0.1								
2 Axle,6T SU	1824274	2.8				***4-Lane TI***				
3 Axle SU	194450	0.3				Lanes				
			10 yr ESAL	Cumulative						
4+ Axle SU	8430	0	Constant	ESAL		1	2	3	4	Total
< 4 Axle ST	283954	0.4	1,840	522,475,360		15.6500205	15.6500205	18.45695485	18.45695485	68.21395069
5 Axle ST	1228312	1.9	6,890	8,463,069,680		21.79921732	21.79921732	25.70905066	25.70905066	95.01653595
6+ Axle ST	11278	0	6,890	77,705,420		12.47466194	12.47466194	14.71207479	14.71207479	54.37347346
< 5 Axle MT	111232	0.2	6,890	766,388,480		16.38002296	16.38002296	19.31788806	19.31788806	71.39582203
6 Axle MT	13243	0	6,890	91,244,270		12.71538591	12.71538591	14.99597419	14.99597419	55.42272021
7+ Axle MT	1269	0	6,890	8,743,410		9.618893125	9.618893125	11.34410502	11.34410502	41.92599629
User-Def	60238	0.1			SUM	88.63820175	88.63820175	104.5360476	104.5360476	386.3484986
Unknown	51347	0.1								
					AVG	16.09785411		5-Axle AVG	23.75413399	

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 07

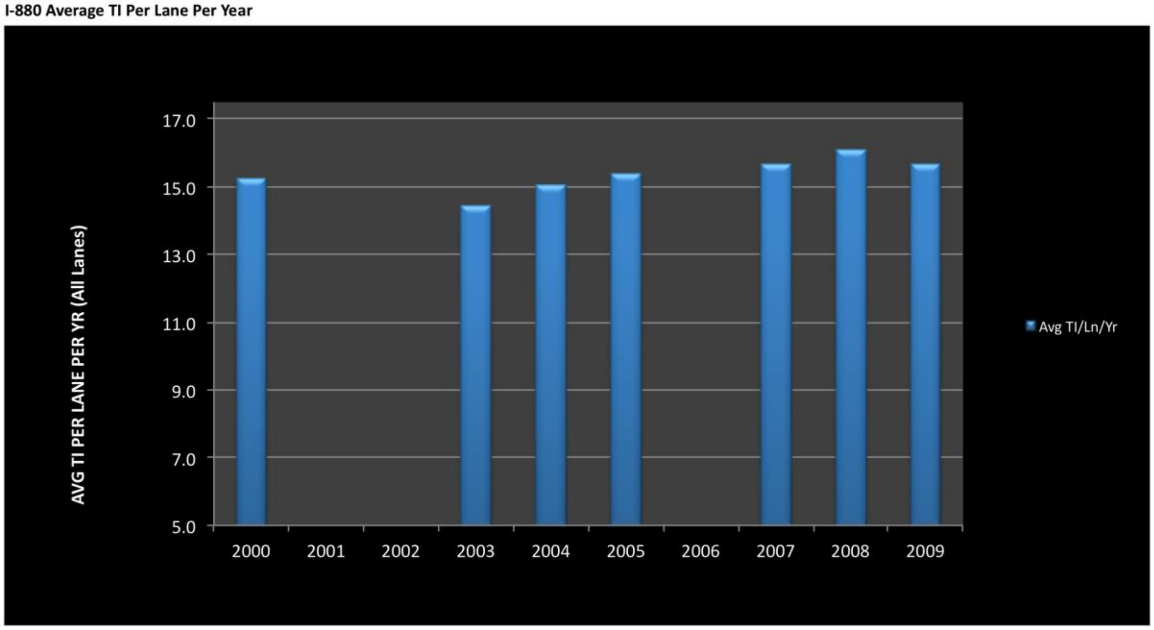
Vehicle Class	# Vehicles	% Total								
Motorcycles	337680	0.5								
Cars	49822055	77.8								
2 Axle, 4T SU	10264147	16								
Bus	84074	0.1								
2 Axle,6T SU	1804967	2.8				***4-Lane TI***				
3 Axle SU	182846	0.3				Lanes				
			10 yr ESAL	Cumulative						
4+ Axle SU	6788	0	Constant	ESAL		1	2	3	4	Total
< 4 Axle ST	254366	0.4	1,840	468,033,440		15.44642671	15.44642671	18.21684517	18.21684517	67.32654375
5 Axle ST	1074380	1.7	6,890	7,402,478,200		21.45462649	21.45462649	25.30265519	25.30265519	93.51456336
6+ Axle ST	8570	0	6,890	59,047,300		12.0736306	12.0736306	14.23911584	14.23911584	52.62549287
< 5 Axle MT	74686	0.1	6,890	514,586,540		15.62171215	15.62171215	18.42356921	18.42356921	68.09056272
6 Axle MT	10887	0	6,890	75,011,430		12.42239243	12.42239243	14.65043041	14.65043041	54.14564569
7+ Axle MT	895	0	6,890	6,166,550		9.227416152	9.227416152	10.88241407	10.88241407	40.21966044
User-Def	54799	0.1			SUM	86.24620454	86.24620454	101.7150299	101.7150299	375.9224688
Unknown	47794	0.1								
					AVG	15.6634362		5-Axle AVG	23.37864084	

Census Station 49090 - I-880 - Summary Table - Vehicle Classification - Jan 1-Dec 31 09

I-880 Average TI Per Lane Per Year

	TI
2000	15.2397
2001	
2002	
2003	14.4393
2004	15.0351
2005	15.3676
2006	
2007	15.6696
2008	16.0979
2009	15.6634
Difference	***0.4237***
% Change	***0.0278***
Average	***15.3589***

I-880 Average TI Per Lane Per Year



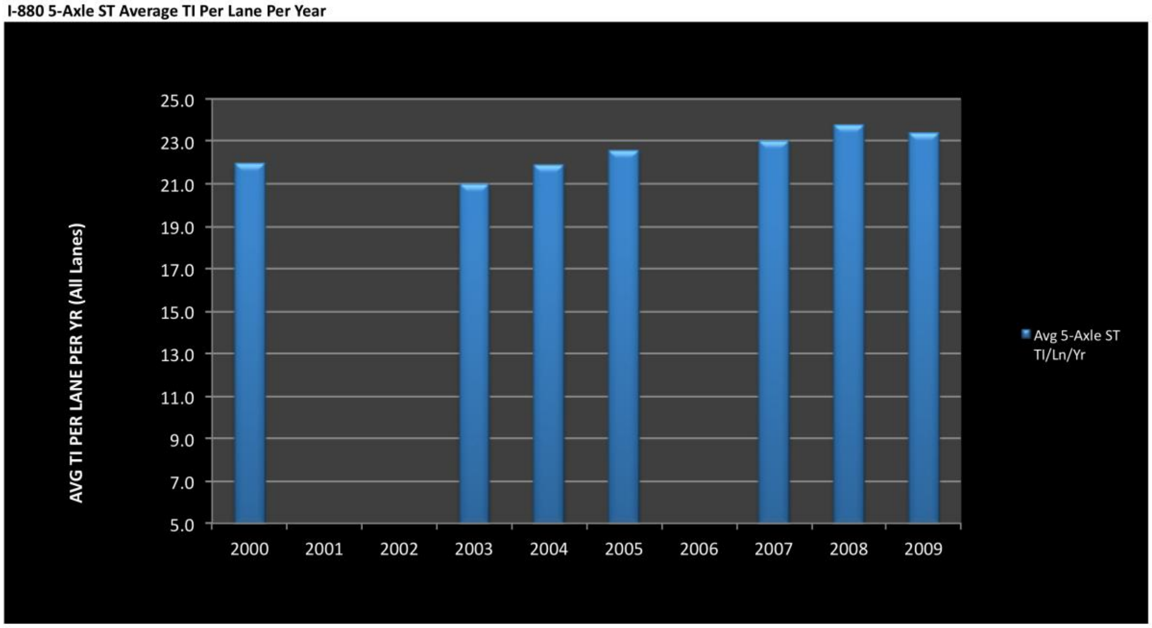
I-880 5-Axle ST TI Per Lane Per Year

	Lanes			
	1	2	3	4
2000	20.1077	20.1077	23.7141	23.7141
2001				
2002				
2003	19.2518	19.2518	22.7048	22.7048
2004	20.0606	20.0606	23.6586	23.6586
2005	20.6648	20.6648	24.3712	24.3712
2006				
2007	21.1377	21.1377	24.9289	24.9289
2008	21.7992	21.7992	25.7091	25.7091
2009	21.4546	21.4546	25.3027	25.3027
Difference	***1.6915***	***1.6915***	***1.9949***	***1.9949***
% Change	***8.41%***	***8.41%***	***8.41%***	***8.41%***
Average	***20.6395***	***20.6395***	***24.3413***	***24.3413***
Overall Avg.		***22.4904***		

I-880 5-Axle ST Average TI Per Lane Per Year

	TI
2000	21.9109
2001	
2002	
2003	20.9783
2004	21.8596
2005	22.5180
2006	
2007	23.0333
2008	23.7541
2009	23.3786
Difference	***1.4677***
% Change	***6.70%***
Average	***22.4904***

I-880 5-Axle ST Average TI Per Lane Per Year



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